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Black Gum (*Nyssa sylvatica* Marsh) in New Hampshire

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April 2000

A report submitted to the U.S. Environmental Protection Agency by the
New Hampshire Natural Heritage Inventory - DRED Division of Forests & Lands (Concord, NH)
and The Nature Conservancy

A Quick Overview of the NH Natural Heritage Inventory's Purpose and Policies

The Natural Heritage Inventory is mandated by the Native Plant Protection Act of 1987 (NH RSA 217-A) to determine protective measures and requirements necessary for the survival of native plant species in the state, to investigate the condition and degree of rarity of plant species, and to distribute information regarding the condition and protection of these species and their habitats.

The Natural Heritage Inventory provides information to facilitate informed land-use decision-making. We are not a regulatory agency; instead, we work with landowners and land managers to help them protect the State's natural heritage and meet their land-use needs.

The Natural Heritage Inventory has three facets:

Inventory involves identifying new occurrences of sensitive species and classifying New Hampshire's biodiversity. We currently study more than 600 plant and animal species and 120 natural communities. Surveys for rarities on private lands are conducted only with landowner permission.

Tracking is the management of occurrence data. Our database currently contains information about more than 4,000 plant, animal, and natural community occurrences in New Hampshire.

Interpretation is the communication of Natural Heritage Inventory information. Our goal is to cooperate with public and private land managers to help them *protect* rare species populations and exemplary natural communities.

cover: 679 and 626 year old black gum (Nyssa sylvatica) trees in Rockingham County, New Hampshire

Photograph by Daniel Sperduto

This project was conducted with funds provided by the U.S. Environmental Protection Agency

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Acknowledgements

Special thanks are due to the many people who played a role in this project. Sara Cairns compiled historical information from the NH Heritage database (BCD) and managed data entry into BCD for the project. David VanLuven assisted with project planning, management, and report editing. Natalie Cleavitt identified moss collections from black gum swamps. Renee Goyette and Shannon Cromley assisted with landowner contact and data entry. Special thanks to Molly Sperduto for numerous search efforts for black gum swamps. Visits to several black gum swamps were conducted prior to this study by NH Heritage staff or contractors including Tom Rawinski, Clotilde Straus, Andy Cutko, and Liz Harvey.

Thanks to conservation commissions, resource professionals, and other knowledgeable individuals that helped identify, confirm, and determine the general size and condition of several black gum populations and to the many landowners that granted us permission to enter their lands. They include Phil Auger, Paul Krusick, Brendan Buckley, Cynthia Wilson, David Allen, David Belknap, Deb Dunlop, Eric Swope, Fran Gordon, George Bailey, Harvey Dupuis, Jerry Langdon, John Rexford, Josh Royte, Laura Nichols, Lenny Lord, Linea Silver, Meade Cadot, Rich Cook, Rick Van de Poll, Tom Conry, Brad Wamsley, Ted Young, Gary Young, Amanda Stone, Imants Millers, Dick Snow, Matt Smith, Tad Zebryk, Pat McCarthy, Lee Kanter, Liz Harvey Ober, Bruce Beckley, Jon Nute, Nancy Voorhis, Karlene Schwartz, Walter Gladstone, Dave Conant, Mark West, Dianne Brennan, Charlie Cogbill, Helen Van Ham, and Susan Williams.

We thank Paul Krusick and Peter Brown for organizing the seventh annual North American Dendroecological Fieldweek in New Hampshire in 1996, and the other members of the black gum research group: Ed Berg, Jim Speer, Ricardo Villalba, and Judith Grable.

A pilot-project conducted by Dave Justice and Fay Rubin at the UNH Complex Systems Research Center under the auspices of this study used both traditional and new remote sensing imagery techniques to predict the locations of black gum swamps. The late Henry Baldwin deserves mention for his insight to establish and re-sample a permanent plot for 40 years in a black gum swamp in Hillsborough, NH, and Albion Hodgdon for his early description of several black gum swamps (summarized in Lyons (1971)). Over the years, many other biologists have provided valuable information that has contributed to the New Hampshire Natural Heritage Inventory database and set the context for this project. Many thanks to all of you for your contributions.

SUMMARY

Black gum (*Nyssa sylvatica* Marsh) is a widespread species of eastern North America, ranging from southwestern Maine west to Michigan, and south to eastern Texas and southern Florida. Within New England, black gum is an occasional tree found in various, usually moist to wet, habitats. It extends throughout southern New England and into southeastern Vermont, through southern, coastal, and east central New Hampshire, and into south coastal Maine. It is disjunct in the Vermont portion of the Champlain Valley. Black gum–red maple basin swamps contain the highest concentrations of black gum trees in New Hampshire, and are a rare, easily overlooked, and poorly understood wetland type in New England.

The NH Natural Heritage Inventory identified known and potential black gum sites in New Hampshire by consulting and interpreting a broad variety of sources. Field surveys were conducted from 1996–1999 to characterize black gum swamps including their size, composition, and overall extent. At 23 of the sites we visited, we sampled 31 plots to obtain more detailed information on the overall composition and structure of black gum swamps, including determination of *Sphagnum* species. We added 15 plots to the data set from existing sources, and produced a classification of black gum swamps based on these data using several classification and ordination programs. We recorded 180 vascular and non-vascular species in black gum swamps in New Hampshire.

We have documented black gum at 112 sites in the state. Many of these sites consist of only a few individuals or have not been thoroughly surveyed, while the largest contain several hundred trees. All occur at elevations of less than 1000 ft. In the northern part of its range in New Hampshire, black gum only occurs on or near the edges of moderate to large lakes (> 1000 acres). Black gum in New Hampshire rarely occurs in upland settings, and then usually only immediately adjacent to more typical wetland habitats. It reaches its greatest abundance and frequency in basin swamp settings and on a few lakeshores. However, black gum is an occasional minor associate in or along floodplain forests, riverbanks, other swamp types, and the borders of salt and freshwater marshes.

Classification and ordination of black gum basin swamp vegetation data suggest that black gum swamps in New Hampshire are remarkably similar in many respects, but can be divided into three principal variants. The definition of these variants was based on variation in plant species composition. This variation relates well to the abundance of tree versus shrub cover. The three variants are:

1. boggy woodland/tall shrub thicket variant: woodlands (25-65% tree cover) or sparse, open-canopy woodlands with a abundant cover of tall shrubs;
2. boggy forest/woodland variant: forests (> 65% tree cover) or woodlands with a significant component of *Picea rubens* (red spruce) and/or *Pinus strobus* (white pine) in the tree canopy or understory, with *Sphagnum* species typical of more nutrient-poor conditions than found in other black gum habitats; and
3. hemlock forest/woodland variant: forests or woodlands often with a strong *Tsuga canadensis* (hemlock) component in the tree canopy and understory, with *Sphagnum* and herbaceous

plant species indicative of slightly more minerotrophic (nutrient rich) conditions than in other black gum habitats.

Stand structure (vertical and horizontal abundance of tree, shrub, and herb layers) varied considerably among plots both within and between variants. However, the three variants did differ from one another structurally on average. Despite variation from plot to plot in structure, nearly all plots in all variants had a wide range of size classes of black gum present.

Black gum is apparently the longest-lived broadleaf deciduous tree in North America. We have documented six sites in New Hampshire that have black gum trees older than 500 years of age, with the oldest individual at one of these sites exceeding 679 years. We counted tree rings in cores taken from one to five trees at each of 20 sites. Cores from 28 trees were counted from one other site where beavers had recently killed all of the black gum in a large, 20-acre basin. Nineteen of these 21 sites contain trees that exceed 200 years of age, 13 contain trees more than 300 years old, and eight contain trees that exceed 400 years.

There is a good general relationship between age of black gum trees and their diameter at breast height. While there is a wide variance in age among large black gum greater than 20 inches, none were less than 225 years of age, and only two of 19 trees above 25 inches were less than 300 years old. The vast majority of trees over 15 inches were more than 200 years old. Many black gum swamps in New Hampshire have a distinct mixed age structure, including old-age black gum, indicating that black gum swamps are structured primarily through single-tree replacement dynamics rather than large scale blowdown events that affect the entire stand. Black gum's longevity, ability to produce root and stump sprouts from a clonal root system, and tolerance of hundreds of years of hurricanes and other disturbances appear to be important life history traits that help maintain numerous uneven-aged, old growth examples of black gum swamps in New Hampshire. As black gum is clonal, total ages of genetic individuals may be much greater than the current standing stem ages, making it conceivable that some individuals exceed 1,000 years of age.

INTRODUCTION

In the New England region, black gum (*Nyssa sylvatica* Marsh) is an occasional tree found in various habitats. Black gum–red maple basin swamps (Sperduto 1997; hereafter referred to as black gum swamps) that contain numerous black gum trees are an uncommon to rare, frequently overlooked, and poorly understood wetland type in New Hampshire. This study of the extent and character of black gum swamps throughout the state was prompted by the discovery of numerous old trees by NH Natural Heritage Inventory (NH Heritage) ecologists and others. These old trees indicated the potential for pockets of old growth – a rare and highly significant forest condition in the Northeast – in the midst of moderately to heavily developed southern New Hampshire.

Largely ignored during periods of heavy logging activity because black gum was not commercially valuable, many black gum swamps are now threatened by beaver- and human-induced flooding, development, logging, drainage alteration, filling of wetlands, and pollution. The primary goal of this project is to inform protection and management decisions concerning black gum swamps in New Hampshire by identifying the locations, characteristics, and significance of these swamps. Specific project objectives were: (1) to identify and inventory black gum swamps in New Hampshire; (2) to characterize the ecological characteristics of black gum swamps and establish a classification of New Hampshire examples; and (3) to identify and describe the highest quality black gum swamps in the state. Funding for this study was provided by the U.S. Environmental Protection Agency through the State Development Wetland Protection grant program.

DISTRIBUTION

Black gum is a widespread species of eastern North America, ranging from southwestern Maine west to Michigan, and south to eastern Texas and southern Florida (Figure 1). Disjunct localities are found in central and southern Mexico. In central and southern portions of its range, it is found from upland xeric sites to moist lowlands that are occasionally inundated by water, but never for long periods. Black gum reaches its best development on well drained, light textured soils, alluvial stream bottoms, and loamy lower slopes and coves. In the northern extremes of its range, it is primarily associated with swamps and the margins of swamps and lakes (Hersey 1774; Otis 1931; Baldwin 1936 and 1978; Fernald 1950; Vogelmann 1969 and 1976; Fosberg and Blunt 1970; Lyons 1971; Eastman 1977; Zebryk 1990; Sperduto 1994). Within New England, the species' essentially continuous range extends throughout Connecticut, Rhode Island, and Massachusetts (though it is less abundant in the Berkshire highlands), into southeastern Vermont, through southern, coastal, and east central New Hampshire and into south coastal Maine (Seymour 1993). It is disjunct in the Champlain Valley in Vermont.

Within New Hampshire, the earliest record of black gum that we encountered was that of James Hersey (Hersey 1774), who marked a "peartree or button tree" on his 1774 survey map of the town of Ossipee. His survey line description read, "…thence keeping ye Course of Ossipee Pond to a Pear tree: Standing by ye side of Said Pond, Spoted and Market, with ye Date of ye year 1774, & with letters JH: AL: JL: BB: JF." This is clearly in reference to a lakeshore

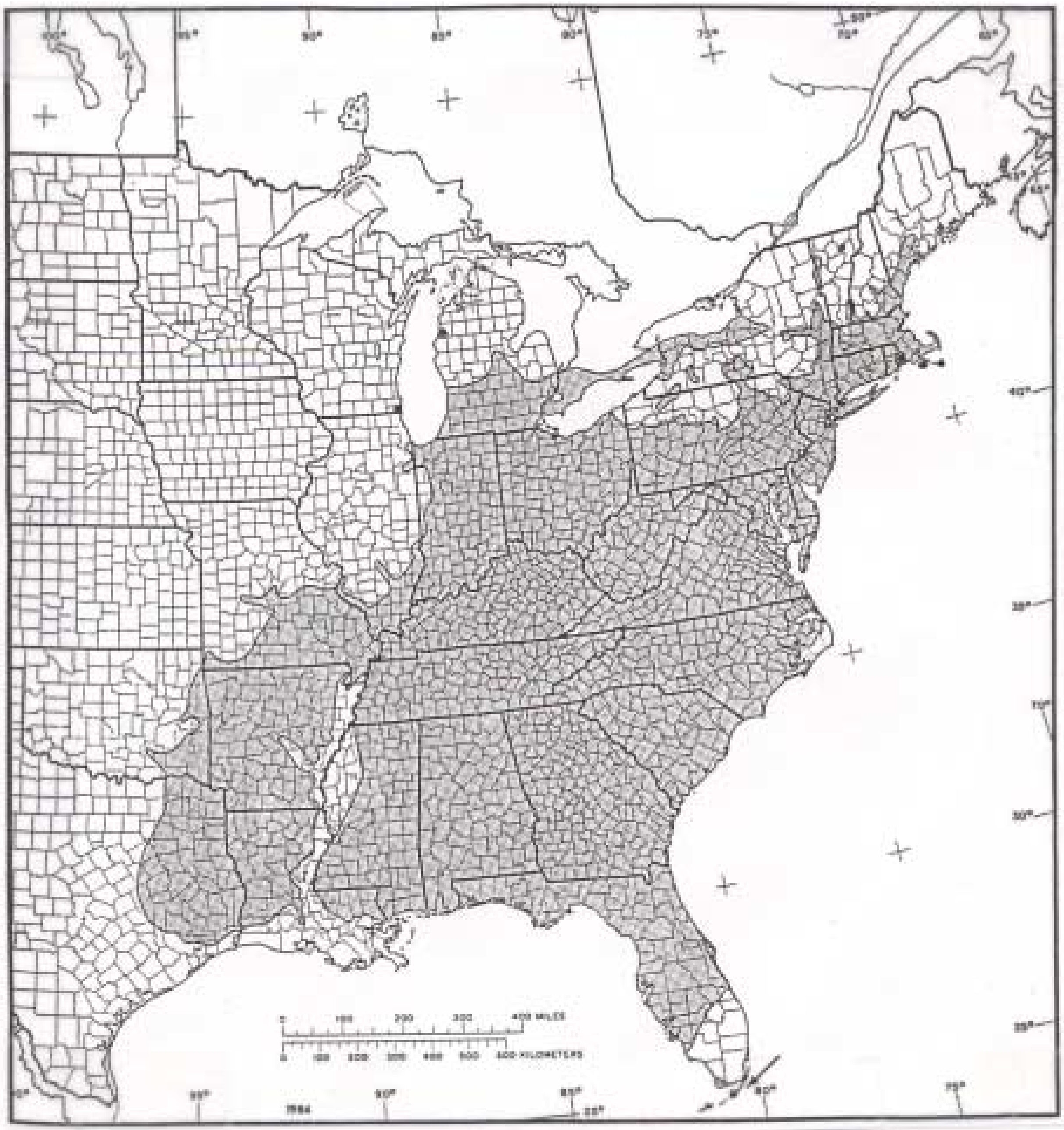


Figure 1. The native range of black gum (*Nyssa sylvatica*) (from McGee 1990).

occurrence of the species. Other references include periodic reports from the 1900's including Baldwin (1936; 1961; 1978), several descriptions of black gum swamps in Lyons (1971), and other swamps described by Sperduto (1994).

TAXONOMY/NOMENCLATURE

The genus *Nyssa* belongs to the Dogwood family (Cornaceae), and contains five species in North America, one in Costa Rica, and four in eastern and southeastern Asia (Wen and Stuessy 1993). In the northeastern United States, it is represented only by black gum (*Nyssa sylvatica* Marsh). *Nyssa sylvatica* has commonly been segregated into *N. sylvatica* var. *sylvatica* (black gum) and *N. sylvatica* var. *biflora* (swamp tupelo), of which only *N. sylvatica* var. *sylvatica* occurs in the northeast. Other taxonomists have treated the two taxa as separate species. Research on differences in growth and development, flooding tolerance, and morphological features (Applequist 1959; Keeley 1977 and 1979) has supported the separation of the two taxa at the species level, with black gum exhibiting a wider range of moisture tolerance and correspondence to distinct ecotypes (Keeley 1979). Recent genetic evidence (Burckhalter 1990 and 1992) has provided definitive evidence that the two are distinct species (*N. sylvatica* and *N. biflora*). *Nyssa biflora* occurs exclusively in inundated swamp habitats in the southeastern United States, whereas *N. sylvatica* occurs in upland and lowland habitats but cannot tolerate inundated situations for extended periods (Applequist 1959; Keeley 1977 and 1979; Burckhalter 1992).

There have been many common name references for *Nyssa sylvatica*, including black tupelo, pepperidge, sourgum, buttonwood, umbrella tree, beetlebung, and even pear tree by some early settlers. Little reason seems to accompany the assignment of the name "gum" to this species, as it produces none. In contrast, tupelo is an apparent adaptation from the Native American Creek language, with *eto* meaning "tree" and *opelwv* meaning "swamp" (Peattie 1964). The derivation of its scientific name is perhaps more descriptive of this tree's elusive character in the north, with *Nyssa* being the name of a water nymph in classical mythology and *sylvatica* meaning "of the forest."

WOOD CHARACTERISTICS

Black gum has interlocking grain (similar to elm), and produces a light, medium-soft, medium-strong, very tough, and difficult-to-split wood that warps on drying. These characters have limited its value as a timber tree, particularly in the north where it is less abundant and has never been of commercial importance. Its unyielding characters, however, have made it good for certain uses including pallets, crossties, containers, wharves, docks, fish weirs, buttons, tool handles, gun stocks, scaffolding, and wooden machinery parts (Peattie 1964; Elias 1980; McGee 1990).

LIFE HISTORY

Black gum is considered to be tolerant of shade. It has separate male and female plants (dioecious), and flowers emerge in the spring when leaves are nearly grown. Fruits ripen and drop in the fall, and are eaten and distributed by small mammals and birds (McGee 1990).

Growth from seed occurs in spring following overwintering and apparently requires nearly full light for optimum early growth, but can otherwise tolerate considerable overstory competition and unfavorable conditions (McGee 1990). Black gum also frequently reproduces from stump sprouts (McGee 1990). Zebryk (1990) excavated the root system of a black gum hummock in Orange, Massachusetts and confirmed that black gum not only stump sprouts but is definitively clonal. Cloning was not limited to the base of the tree: one stem (ramet) emerged from a wet hollow connected by a common root system to the main stem nearly three meters distant. Excavation beyond this distance was not attempted. Zebryk (1990) suggests that black gum's clonal strategy may account for the clumped distributions of black gum at the study site.

Orwig and Abrams (1994) have described black gum as a gap-facultative species that can persist in the subcanopy and then release, even after 170 years. In a study of mid-late successional oak stands in Virginia, they found multiple release and suppression periods. The major releases coincided with logging in the late 1800's and early 1900's, whereas the more frequent moderate releases were not well synchronized and reflected local gap dynamics. Other studies in southeastern forests indicate that large numbers of seedlings can become established when black gum are cut, and 25% or more of established seedlings can be expected to respond with relatively rapid growth (McGee 1990). It is unknown whether black gum has similar responses to gap formation and cutting under different ecological conditions in different portions of its range, particularly in northern basin swamp settings. Diameter and height growth can be very slow on poorer sites or where the tree is under heavy competition (Putnam 1951). Young sprouts are browsed by white tail deer, but lose palatability with age (McGee 1990).

The form of black gum is distinct, with crooked trunks and gnarled branches being common features, and a "stag-headed" appearance to the tops of older trees created by an increasingly diminutive crown of branches as they snap off over time. Old trees often exhibit thick, little-tapered trunks below the stag-head tops and deeply furrowed bark which may be much smoother on the upper side of a leaning stem. The branches produce short spur twigs that emerge at right angles to the stem. The branch and twig pattern is most pronounced in fall and winter when no leaves are present.

According to McGee (1990) black gum rarely achieves dominance within its age class, except in the mountains where it can be among the canopy dominants. However, it is noted among the dominant canopy trees in many swamps in the northern portion of its range (Lyons 1971; Vogelmann 1976; Baldwin 1978; Zebryk 1990) and apparently in some maritime upland forest settings in southern New England (Dunwiddie 1991).

Black gum is a long lived species with reports (prior to this study) of 177 years in Maine (Vogelmann 1976), more than 200 years in New Hampshire (Baldwin 1978), and 300 years (Dunwiddie 1991) and nearly 400 years (Zebryk 1990) in Massachusetts. Vogelmann (1976) estimated that some of the trees at his Maine study site could exceed 400 years based on growth rate extrapolation for trees with rotten cores.

COMMUNITY/HABITAT CHARACTERISTICS

The few existing descriptions of northern New England black gum occurrences prior to this study indicate that most sites had very similar hydrologic settings and floristic compositions (Baldwin 1936 and 1978; Vogelmann 1969 and 1976; Lyons 1971; Zebryk 1990; Sperduto 1994). Nearly all were small, acidic peatland swamps with a mixed canopy composition of black gum, red maple, and other trees, an acidic understory species composition, and limited drainage in non-alluvial settings. A few lakeshore populations were also mentioned (Lyons 1971). Baldwin recorded changes in tree composition and abundance over a 40-year time frame in a southern New Hampshire black gum swamp (Baldwin 1978). Zebryk conducted a detailed study of a single swamp system in Orange, Massachusetts, including profiles of the distribution and abundance of trees, surface water pH, and sediment depth and type. Dunwiddie (1991) described the forest history and composition of a coastal island pond in Plymouth County, Massachusetts that contained considerable black gum in an upland forest setting.

NH HERITAGE ECOLOGICAL APPROACH

NATURAL COMMUNITIES

NH Heritage classifies the landscape with "natural communities," which are recurring assemblages of species found in particular physical environments. Each natural community type is distinguished by three characteristics: (1) a definite plant species composition; (2) a consistent physical structure (such as forest, shrubland, or grassland); and (3) a specific set of physical conditions (such as different combinations of nutrients, drainage, and climate conditions). Natural communities include both wetland types (e.g., red maple basin swamp) and uplands such as woodlands (e.g., rich red oak-sugar maple/ironwood talus forest/woodland) and forests (e.g., hemlock-beech-oak-pine).

While natural community names can be similar to the names of Society of American Foresters (SAF) forest cover types, natural communities are defined using a broader range of considerations. SAF forest cover types are primarily based on dominant tree species, while natural communities are based on all species, the structure of these species, and the specific physical environment. Trees are often subtle indicators of their environments. A number of natural communities can be distinguished based largely on trees, and in some cases differences in tree composition are the main difference between two community types. However, some trees are so broadly adapted that their presence does not precisely indicate site conditions (e.g., white pine or red maple), or differences in species primarily relate to cutting or other disturbances.

For example, there are four SAF spruce-fir cover types that correspond to the "montane spruce-fir forest" natural community type. These different cover types primarily relate to stand disturbance history or the successional stage rather than to major environmental differences. The four cover types also do not differentiate between upland spruce-fir forests and spruce-fir swamps. When one considers understory species and soils, upland spruce-fir forests are markedly different from the red spruce/sphagnum basin swamp natural community. In fact, the differences between these two natural communities are more dramatic than the internal differences between the four SAF spruce-fir cover types. SAF cover types are, however, useful for timber management.

Natural community types and the US Forest Service’s Ecological Land Types (ELTs) are not easily comparable for three primary reasons. First, ELTs are mapped at units of 100 or more acres, so some natural communities occur as smaller patches within various ELT types. Second, ELTs do not reflect major differences in soil nutrient status while natural communities do. Third, ELTs describe fine-scale soil characteristics that may have silvicultural significance but sometimes have no corresponding floristic expression.

Natural communities form a mosaic across the landscape, and the ecological processes in one community influence those in neighboring communities. Land managers therefore cannot consider a given natural community occurrence in isolation from its surroundings. Further, boundaries between natural community types can be either discrete (and therefore easily identified in the field) or gradual (thus making some areas difficult to map).

NATURAL COMMUNITY CLASSIFICATION

The classification of natural communities in New Hampshire is based on data from more than ten years of ecological research by ecologists with NH Heritage and The Nature Conservancy, plus extensive reviews of scientific literature. These data have been compiled and arranged into natural community types in part through the use of ordination and other statistical methods. Most state natural heritage programs continually update their classifications and cooperate with The Nature Conservancy's regional and national ecologists to ensure that natural community types are comparable across state lines.

The names of natural community types generally begin with the dominant or most characteristic plant species, and may include the name of a landscape feature or vegetative structure that is typical of that community type. For example, black gum–red maple basin swamp refers to a basin swamp (a specific hydrologic setting, as opposed to a streamside swamp) with black gum *and* red maple in the canopy. In addition, like all SAF forest cover types, forested natural communities may have considerable overlapping species and other characteristics, but they contain distinct and diagnostic combinations of species and physical characteristics. For example, the red spruce-northern hardwood natural community has considerably more red spruce in the overstory, and is generally higher in elevation, than the standard northern hardwood forest (sugar maple-beech-yellow birch forest natural community) despite many species that occur in both.

EXEMPLARY NATURAL COMMUNITIES

NH Heritage places particular emphasis on, and gives conservation priority to "exemplary" natural communities. Exemplary natural communities include all examples of rare types (such as a rich mesic forest) and high-quality examples of common types. High-quality sites are identified by having relatively little human impacts. These areas have greater potential to contain or achieve natural dynamics that are characteristic of the original forests. A forested natural community need not be "old growth" to obtain exemplary status. Typical exemplary forested natural communities have a variety of characteristic species, natural regeneration within forested gaps, multiple age classes, diverse structural characteristics, abundant standing and fallen woody debris, intact soil processes, and a lack of direct evidence of human disturbance. Such characteristics can only be studied, preserved, and understood by having appropriate reference sites. Further, exemplary natural communities represent the best remaining examples of New Hampshire's flora, fauna, and underlying ecological processes.

The effects of the 1998 ice storms do not preclude any natural community from being designated exemplary. Damage caused by natural disturbances, including ice storms, blow-downs, and fire, are part the suite of natural processes influencing forest dynamics. We take heavy ice damage into account when assessing natural communities, but if the stand also displays exemplary attributes, including minimal human influence, then we are likely to classify it as such.

RARITY

NH Heritage considers the rarity of a natural community or a species both within New Hampshire and across its total range. We identify the degree of rarity within New Hampshire with a "State Rank" and throughout its range with a "Global Rank." Ranks are on a scale of 1 to 5, with a 1 indicating critical imperilment, a 3 indicating that the species is uncommon, and a 5 indicating that the species or natural community is common and demonstrably secure (see Appendix 1 for more details). Species and natural communities considered to be “globally rare” or “state rare” are those designated G1-G3 or S1-S3, respectively. Some species are rare both globally and in New Hampshire (e.g., G2 S1), while others are common elsewhere but rare in New Hampshire (e.g., G5 S1). Many communities have not been assigned global ranks at this time, pending a comprehensive review of their status and distribution range-wide.

QUALITY RANKS

In addition to considering the rarity of a natural community or species as a whole, NH Heritage ranks the quality of individual natural community occurrences and rare plant populations. These "Quality Ranks" give a more detailed picture of significance and conservation value. Quality ranks are based on the *size*, *condition*, and *landscape context* of a natural community or rare species population. These terms collectively refer to the integrity of natural processes or the degree of human disturbances that may sustain or threaten long-term survival. There are four quality ranks:

<u>Rank</u> <u>Description</u>

A **Excellent Occurrence:** An A-ranked natural community is a large site nearly undisturbed by humans or which has nearly recovered from early human disturbance and will continue to remain viable if protected. An A-ranked rare species occurrence is large in both area and number of individuals, is stable, exhibits good reproduction, exists in a natural habitat, and is not subject to unmanageable threats.

B **Good Occurrence:** A B-ranked community is still recovering from early disturbance or recent light disturbance by humans and/or may be too small in size and viability to be an A-ranked occurrence. A B-ranked population of a rare species occurrence is at least stable, grows in a minimally human-disturbed habitat, and is of moderate size and number.

C **Fair Occurrence:** A C-ranked natural community is in an early stage of recovery from disturbance by humans and/or a small sized representative of the particular type of community. A C-ranked population of a rare species is in a clearly human-disturbed habitat and/or small in size and/or number, and possibly declining.

D **Poor Occurrence:** A D-ranked natural community is severely disturbed by humans, its structure and composition are greatly altered, and recovery is unlikely except in the very long term. A D-ranked occurrence of a rare species is very small, has a high likelihood of dying out or being destroyed, and exists in a highly human-disturbed and vulnerable habitat.

For example, consider a population of a rare orchid growing in a bog that has a highway running along one border. The population may be large and apparently healthy (large *size* and intact *condition*), but the long-term threats posed by disturbance at the bog's edge -- its low-quality *landscape context* (pollution from cars and roads, road-fill, garbage, altered hydrology, reduced seed dispersal, etc.) -- may reduce the population's long-term viability. Such a population of orchids would receive a lower rank than a population of equal *size* and *condition* in a bog completely surrounded by a forest (i.e., with a higher quality *landscape context*).

NH Heritage, in collaboration with other state heritage programs and The Nature Conservancy, is working to develop quality rank specifications for all of New Hampshire's natural communities and rare plant species. Unfortunately, limited time and incomplete knowledge, both on local and global scales, have prevented the development of thoroughly tested and peer reviewed quality rank specifications for most of New Hampshire's natural communities and rare species.

In the absence of rank specifications for each natural community, NH Heritage uses broad guidelines for assigning preliminary quality ranks. The guidelines for assessing the size, condition, and landscape context for natural communities are described below.

Size

Occurrence size is a quantitative measure of area occupied by a species or natural community and accounts for such factors as population abundance, fluctuation, density, and area of occupancy for species. All else being equal, the larger a natural community is, the more viable it will be. Large size is correlated with increased heterogeneity of internal environmental conditions, integrity of ecological processes, species richness and size of constituent species populations and their respective viability, potential resistance to change, resilience against perturbations, and ability to absorb disturbances. Size is used in a relative sense with respect to the range of sizes exhibited by the particular natural community type.

Condition

Condition is a combined measure of the quality of reproduction (for species), development/maturity (for communities), degree of integrity of ecological processes, species composition, biological and physical structure, and abiotic physical factors within the occurrence. For example, old growth forests with little anthropogenic disturbance and intact biotic and abiotic factors, structures, and processes, would warrant an "A" rank for condition regardless of size.

1. **Excellent Condition:** Old growth or minimally disturbed by human impacts with recovery essentially complete, or in the case of disturbance-maintained communities (e.g., pitch pine/scrub oak barrens), the natural disturbance regime has prevailed continuously with no significant or irreversible alterations by humans; ecological processes, species composition, and structural features are intact.
2. **Good Condition:** Mature examples with only minor human impacts or good potential for recovery from relatively minor past human impacts; ecological processes, species composition, and structural features are largely intact.
3. **Fair Condition:** Immature examples or those with significant human impacts with questionable recovery potential or in need of significant management and/or time to recover from present condition; ecological processes, species composition, and structural features have been altered considerably but not to the extent that the occurrence is no longer viable if managed and protected appropriately.
4. **Poor Condition:** Little long term viability potential.

Landscape Context

Landscape context is a combined measure of (a) the quality of landscape structure, (b) the extent (including genetic connectivity), and (c) the condition of the surrounding landscape that influences the occurrence's condition and viability. Dynamic natural community occurrences, including many open natural community types, have a better long-term viability when they are associated with large areas of diverse habitat that support dynamic ecosystem processes. Potential factors to be considered include: (a) the degree of landscape fragmentation; (b) the relationship of a natural community to contiguous wetland or upland natural communities; (c) the influence of the surrounding landscape on susceptibility to disturbance; (d) the relative position in a watershed; (e) susceptibility of the occurrence to pollutants and hydrologic change (Chase *et al*. 1995); and (f) the functional relationship of the natural community to surrounding natural landscape features and larger-scale biotic and abiotic factors. For example, open peatlands are extremely sensitive to nutrient input, basin swamps are moderately sensitive, and streamside/riverside communities and seepage swamps are less sensitive.

In general, landscape condition is weighted towards the immediate 30-300 m (100-1000') buffer area around the natural community where direct impacts of land use may be most significant. The adjacent 1.6-3.2 km^2 (1-2 mi^2) area or relevant watershed area around the natural community is considered to a lesser degree. In turn, the larger area around that receives the least consideration. The actual size applied for a natural community varies according to the characteristics of the particular natural community and the specific context of the occurrence in the landscape.

1. **Excellent Landscape Context:** Natural community is embedded in a matrix of undisturbed, unfragmented surrounding natural communities that have functional connectivity to the occurrence; past human disturbances that potentially influence the community are minimal or negligible.
2. **Good Landscape Context:** Surrounding landscape is largely intact and minimally fragmented, or human disturbance/fragmentation is of a configuration and magnitude that is consistent with maintaining the current condition of the occurrence, or disturbances can be managed to achieve viability.
3. **Fair Landscape Context:** Significant human impacts, development, fragmentation, and other disturbances characterize the landscape around the natural community and may affect the long term viability and condition of the occurrence.
4. **Poor Landscape Context:** Functional human impacts, fragmentation and loss of natural communities dominate the surrounding landscape; the occurrence is probably not viable, even with management.

PROTECTING NEW HAMPSHIRE'S BIODIVERSITY

In 1994, the Northern Forest Lands Council (1994) concluded that "maintaining the region's biodiversity is important in and of itself, but also as a component of stable forest-related economies, forest health, land stewardship, and public understanding." In response to recommendations by the Northern Forest Lands Council, the NH Division of Forests & Lands and the NH Fish & Game Department established the Ecological Reserves System Project. One of the project's primary objectives was to "assess the status of biodiversity in New Hampshire and the extent to which it is protected under the current system of public and private conservation lands" (NH Ecological Reserve System Project 1998b). This question was then explored by a 28-member Scientific Advisory Group who took the question beyond the Northern Forest and considered it in a statewide context. The conclusions of the group indicated that there was a serious need for continued biodiversity conservation in New Hampshire:

> Though conservation lands comprise approximately 20% of the land area in New Hampshire, the current system of conservation lands in New Hampshire does not appear to provide comprehensive, long-term protection of biodiversity at the species, natural community, or landscape levels. (NH Ecological Reserve System Project 1998a)

NH Heritage strives to facilitate protection of the state's biodiversity through the protection of key areas that support rare species, rare types of natural communities, and high quality examples of common natural community types. Exemplary natural communities are particularly important because we assume that if we protect an adequate number of viable examples of each natural community type, we can protect the majority of New Hampshire's species. This is sometimes referred to as a "coarse filter" approach to protecting biodiversity.

The "coarse filter" can miss important species, however, so it needs to be augmented with a finer filter. The "fine filter" approach generally focuses on specific rare species. For example, the rare, federally-threatened *Isotria medeoloides* (small whorled pogonia) occurs in a variety of second-growth hardwood forests in southern New Hampshire. This orchid's habitat may not be captured by the coarse filter approach, so we need to employ a fine filter approach (i.e., survey for the plant itself) to ensure that the species is protected.

Long-term protection of New Hampshire's species, natural communities, and ecological processes requires a variety of conservation approaches. The goal of NH Heritage's coarse and fine-filter approaches is to inform management decisions by identifying those sites that have a relatively greater potential for maintaining the natural diversity within the state.

The foundation for successful biodiversity protection is a series of representative, high-quality examples of all the state's natural community types, with their constituent species and their underlying ecological processes. The best option for this kind of protection would be a series of connected, high quality natural community types; this series would ensure that ecological processes that connect natural communities remain functionally intact within a broader landscape context. In short, there is a need for reserve areas with natural communities protected within a diverse landscape, not just in isolation.

METHODS

LANDSCAPE ANALYSIS

The first step of the inventory is a process called "landscape analysis." All available site data were examined to prioritize survey areas and to increase the efficiency of field visits in potential study areas.

Background research and landscape analysis consisted of several complementary approaches. We compiled existing information and literature on black gum swamps in New Hampshire and the region to determine what was known and to identify information gaps. Potential black gum swamps were identified within the potential range of black gum in the state by searching for certain landscape positions, soil characteristics, and hydrologic settings. Source materials used for this identification included Natural Resource Conservation Service soil surveys, National Wetland Inventory (NWI) maps, surficial (Goldthwait 1950) and bedrock (Lyons *et al*. 1997) geological maps, and U.S. Geological Survey (USGS) topographic quadrangles. In some areas, aerial photographs were reviewed to identify broad vegetation patterns. The NH Heritage database was also reviewed to identify the locations and quality of known black gum swamps within the state. We then categorized areas as high, medium, or low priority for field surveys, depending on their predicted likelihood of supporting exemplary black gum swamps.

REMOTE SENSING

We also identified potential black gum sites by using remote sensing in collaboration with the Complex Systems Research Center at UNH. This pilot project had two stages and utilized

Landsat Thematic Mapper imagery, bands 1-5 (path 12, row 30, acquired 9/90). The first stage used traditional remote sensing techniques on 26 training sites to classify the vegetation on nearly 1.6 million acres in southeastern New Hampshire. Five of the training sites were black gum swamps while the remaining 21 sites represented other communities and landscape features. Locational data for the black gum training sites were collected in the field using GPS equipment (Trimble GeoExplorer II). The second stage involved the application of a new remote sensing technique – sub-pixel classification – to refine the traditional technique. Potential black gum swamps on 35 USGS topographic quadrangles were identified using this new technique. Additional black gum training sites and slope information derived from digital elevation models would further refine the accuracy of the sub-pixel classification technique, but would require funding beyond the scope of this pilot project.

Compilation of Known and Potential Black Gum Sites

Potential black gum swamps were compiled into a geographically organized master list, arranged by topographic quadrangle (Appendix 2). All medium-to-large basins or concentrations of small basins with NWI designations of PFO1E, PFO1/4E, or PFO4/1E were marked on USGS topographic quadrangle maps.[1] Of these wetland basins, the ones with the highest potential for black gum swamps were those that (a) occurred highest in the watershed, (b) coincided with basins identified by the remote sensing pilot-project, (c) were designated PFO1/4E, and (d) had muck and peat soils associated with soil types that were rocky, stony fine sandy loam complexes. Sites where black gum swamps were previously documented and leads from conservation commissions and other knowledgeable organizations and individuals were also listed.

Information Requests

We sent out more than 75 black gum information packets to conservation commissions, resource professionals, and other knowledgeable individuals to help identify, confirm the locations of, and/or determine the general size and condition of black gum populations in the state. This effort was undertaken to augment our landscape analysis with the hope that knowledgeable individuals could provide information about potential high quality sites in their communities.

Landowner Contact

NH Heritage policy dictates that we obtain landowner permission to undertake field surveys on private lands. We therefore attempted to contact private landowners of all high and medium priority study sites. Land ownership was determined by consulting tax maps at town halls. Landowners were then sent a letter explaining our study, a fact sheet describing NH Heritage, and a self-addressed stamped postcard on which they could grant or deny permission for surveys.

[1] Under NWI mapping conventions, the code PFO1E indicates a palustrine, seasonally flooded or saturated, forested wetland dominated by broad-leaved, deciduous canopy species. The codes PFO1/4E and PFO4/1E indicate palustrine, seasonally flooded or saturated, forested wetlands dominated by varying mixtures of broad-leaved deciduous and needle-leaved evergreen canopy species.

Due to the time-intensive nature of this process, we also engaged local conservation commissions directly to assist with some of the landowner contact work.

In some instances, such as very high priority sites for which no response was received, we also attempted to contact landowners by telephone. Great care was taken to undertake field surveys only on properties for which permission was granted.

FIELD SURVEY

To gain a representative understanding of black gum swamps in New Hampshire, fieldwork was conducted at study sites throughout the range of black gum in the state (see Figure 2). Data were collected at specific locations (observation points or OPs) and throughout each wetland, primarily during the 1997 and 1998 field seasons. Additional data collected by NH Heritage and other organizations prior to 1997 were also included in the analysis. The following information was collected at most observation points:

1. natural community type, following Sperduto (1994; 1997);
2. percent coverage estimates for plant species;
3. diameter-at-breast height (DBH) of canopy trees;
4. tree cores from selected stands;
5. other descriptive notes, including the number of black gum present, soil descriptions, other physical site characteristics, and evidence of human disturbance.

For purposes of community classification, at some observation points, more detailed ecological data were collected in 400-m^2 releve plots, including estimated percent cover of all plant species by forest structure (strata) and growth form (canopy trees, subcanopy trees, shrubs, tree seedlings, vines, herbs, ferns, and graminoids). Most plants were identified in the field during the inventory or collected and keyed out using the resources available at NH Heritage. Vascular plant nomenclature follows Gleason and Cronquist (1991) and occasionally Fernald (1950), with common names generally following George (1997). Nomenclature of *Sphagnum* species follows Cleavitt *et al.* (*In press*).

Within each plot, we recorded diameter-at-breast height (DBH) of all trees greater than 2 in. in diameter, including standing dead trees, and noted the degree of decomposition of dead trees. Soil characteristics collected from soil pits at each plot included soil pH and a description of organic soil transitions using the von Post scale of peat decomposition. Micro-topography was also noted.

Within 50-m^2 subplots, the micro-topographic location and percent cover of all *Sphagnum* species were recorded. Samples of *Sphagnum* species were identified by Natalie Cleavitt.[2] Percent cover of *Sphagnum* species within these subplots was used to represent the total cover by *Sphagnum* species within the plot as a whole.

[2] Department of Natural Resources, Cornell University, Ithaca, NY 14853. Current address: Department of Biological Sciences, University of Alberta, Edmonton, AB T6G 2E9.

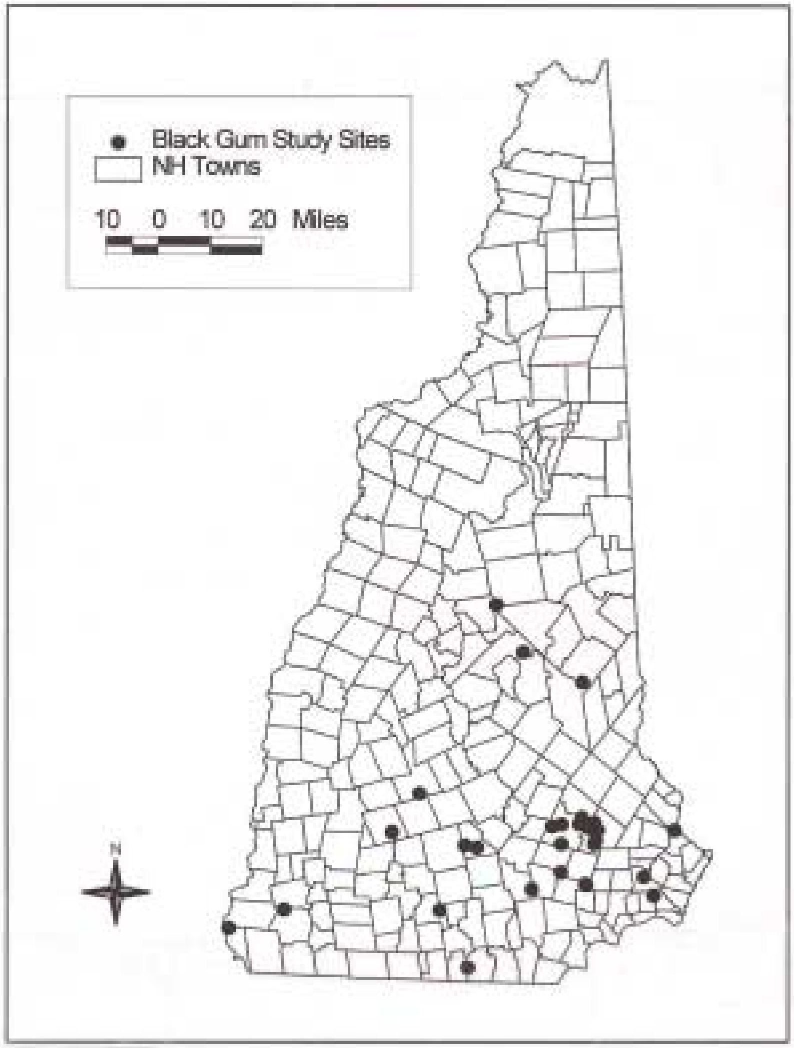


Figure 2. Black gum swamp study sites at which releve data were collected.

NH Heritage prepared descriptions of significant sites to summarize important ecological information, including existing threats and management recommendations. Each site was mapped on a copy of a 1:24,000 scale USGS topographic map, and significant sites were mapped using ArcView GIS version 3.1 (Appendix 9). A Trimble GeoExplorer II Global Positioning System (GPS) was used at selected sites to determine the location of plots or swamps and to gather natural community boundary information. The accuracy of the data collected by the GPS after differential correction was generally plus or minus 5 m.

NATURAL COMMUNITY CLASSIFICATION AND VEGETATION ANALYSIS

To improve our understanding of black gum swamps in New Hampshire, we collected plot data from representative areas with a significant component of black gum in the tree canopy and supplemented these data with existing information from the NH Heritage database. We analyzed the resulting black gum data set using programs in PC-ORD (McCune and Mefford 1997), including Two-way Indicator Species Analysis (TWINSPAN), Detrended Correspondence Analysis

(DCA) based on Hill (1979a, 1979b), and Canonical Correspondence Analysis (CCA) (Ter Braak 1988). From these analyses, we derived a classification of black gum swamps in the state.

Classification attempts to group the array of vegetation represented by a data set into meaningful clusters or groups. These groups represent different segments along an often-continuous gradient of change in vegetation and environmental conditions. TWINSPAN uses a polythetic divisive classification method based on reciprocal averaging (Hill 1979b) that reveals patterns of association among species and samples (plots). The results include a species-by-plots matrix that groups together plots that have similar combinations of species, and differentiates them from other groups that have dissimilar associations of species. TWINSPAN breaks any given data-set into two groups based on the strongest floristic differences in the data, and the program continues to break each resulting group into two additional groups until a specified number of separations has been achieved. It is up to the interpreter to decide where the splits lose ecological meaning and become arbitrary.

DCA ordinates species and sample plots through reciprocal averaging techniques (Hill 1979a; McCune and Mefford 1997). The graphic result is an ordination along two or more axes that reflect differences between plots and species. DCA does not force plots into groups like TWINSPAN, but does provide a graphic portrayal of how similar or different individual plots are from one another in a common "ecological space." A third technique, CCA, combines ordination with regression analyses to portray relationships of species and plots with environmental parameters (Ter Braak 1988; McCune and Mefford 1997).

These multivariate techniques have become popular in ecology, especially in the attempt to classify and ordinate large data sets into ecologically meaningful groups. They have a high utility for helping discern patterns, but they do not provide test results with statistical significance as would analysis of variance, regression, and correlation techniques.

LIMITATIONS OF STUDY

This project focused on the identification of intact, high quality black gum swamps in New Hampshire. Our study efforts focused on relatively large, intact patches that were identified through landscape analysis. Because of the abundance of appropriate landscape signatures and the limitations imposed by contacting and gaining permission from landowners, we were unable to visit every potential site. We also did not seek to inventory small, fragmented patches of known black gum swamps, and it was beyond the scope of this project to document all potential black gum patches of small size or reduced quality.

Not every swamp in the state containing black gum was identified and recorded during this study. This leaves the potential for the discovery of new black gum swamps, particularly given the frequency and small scale of appropriate landscape settings for black gums. Appendix 2 documents potential sites identified during landscape analysis that have not yet been visited by NH Heritage ecologists due to low priority attributes, limitations of landowner contact or access permission, or other reasons. Many of these sites will yield only a few or no black gum trees, but the presence or absence of black gum swamps can, at this time, only be determined through field surveys.

RESULTS AND DISCUSSION

During the 1997 and 1998 field seasons, NH Heritage visited sites identified by the landscape analysis process as likely to contain black gum. We collected releve data at 31 plots in 23 sites. We also recorded descriptive information at additional observation points at each site in order to characterize the overall composition, structure, and extent of each black gum swamp.

To classify and describe black gum swamps in New Hampshire, we compiled a data set of 46 releve plots, which includes both the 1997-1998 field data and additional plot data from the NH Heritage database. This database documents 180 vascular and non-vascular taxa that occur in black gum swamps in New Hampshire. See Appendix 5 for the complete species list.

None of the species documented from the releve plots, which were sampled to characterize the black gum swamps themselves, are considered rare; however, three rare plant species have been documented from other black gum swamps in New Hampshire. These species are *Rhododendron maximum* (giant rhododendron; State Rank S2), *Rhododendron viscosum* (swamp azalea; State Rank S3), and *Chamaecyparis thyoides* (Atlantic white cedar; State Rank S3). NH Heritage also observed two plant species of "special concern" in the state in releve plots established for this project: *Kalmia latifolia* (mountain laurel) and *Sarracenia purpurea* (pitcher-plant); each occurred at four black gum swamp sites.

Analysis of releve plot data using classification and ordination techniques suggests that black gum–red maple basin swamps in New Hampshire fall into three principal variants:[3] boggy woodland/tall shrub thicket, boggy forest/woodland, and hemlock forest/woodland. Each of these variant types is described in detail below. The following sections also describe the results of landowner contact activities; the general habitat, species composition, vegetation structure, age structure, and environmental characteristics of black gum swamps in New Hampshire; criteria for evaluating the quality of black gum swamps; and descriptions of exemplary black gum sites in the state.

RESULTS OF LANDOWNER CONTACT

Over the course of the study, we researched and contacted a total of 338 landowners (for 375 parcels) in 16 towns. Of the 338 landowners, 136 (40%) gave permission to visit their property, 20 (6%) refused permission, and 182 (54%) did not reply. Ninety-eight landowners requested follow-up information. Figure 3 shows the distribution of towns within which NH Heritage requested permission to visit black gum sites.

[3] Variants of communities correspond to differences within a community type that are environmentally based (as opposed to successionally based) and are reflected by relatively minor vegetation differences and minor or major soil differences. This may include a shift in dominant tree species where the understory vegetation remains identical, or a simple shift in abundance of one or more species.

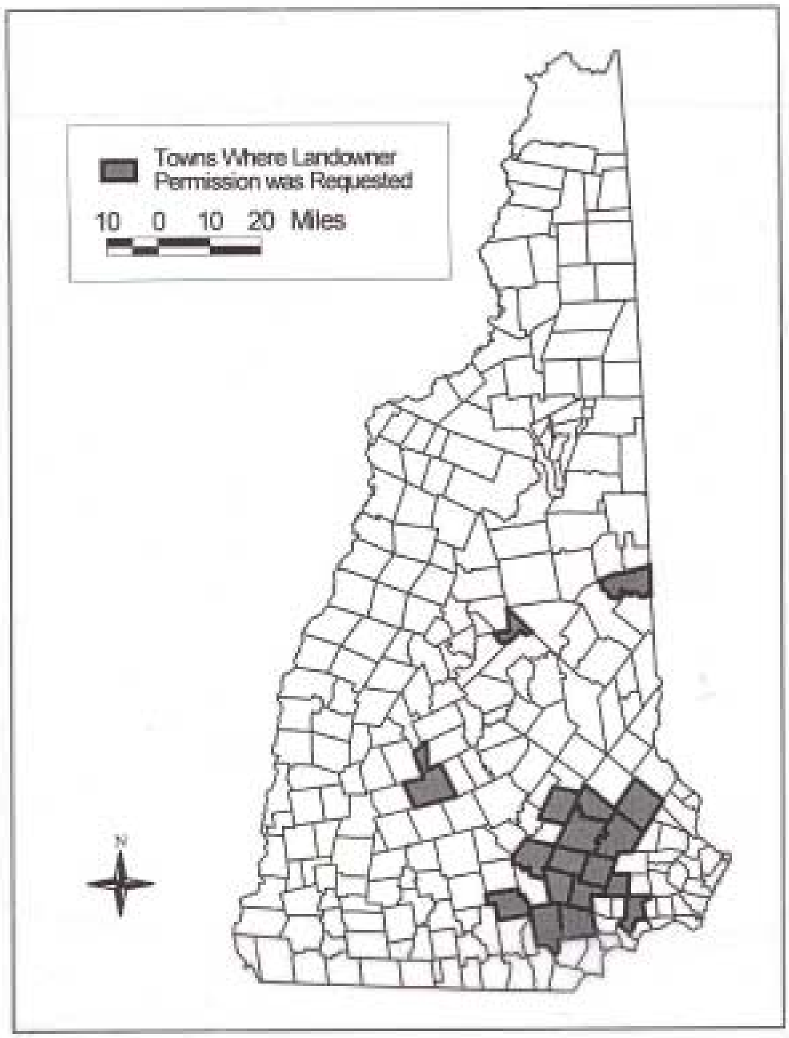


Figure 3. Towns in which NH Heritage requested private landowner permission to visit potential black gum swamp sites.

VEGETATION AND ENVIRONMENTAL CONDITIONS

GENERAL HABITATS OF BLACK GUM IN NEW HAMPSHIRE

We have documented black gum at 112 sites in the state (Figure 4, Appendix 3). Many of these sites consist of only a few individuals or are reports that have not been thoroughly surveyed, while the largest contain several hundred trees. All occur at elevations of less than 1000 ft. In contrast to more central portions of its range, black gum in New Hampshire rarely occurs in upland settings, and then usually only immediately adjacent to more typical wetland habitats. It reaches its greatest abundance and frequency in basin swamp settings. However, black gum is an occasional minor associate in several other habitats. We subjectively grouped all black gum occurrences into four generalized habitat-setting categories, which are summarized briefly below. The remainder of this report focuses on basin swamp and lake-border populations that tend to contain the largest number of black gum.

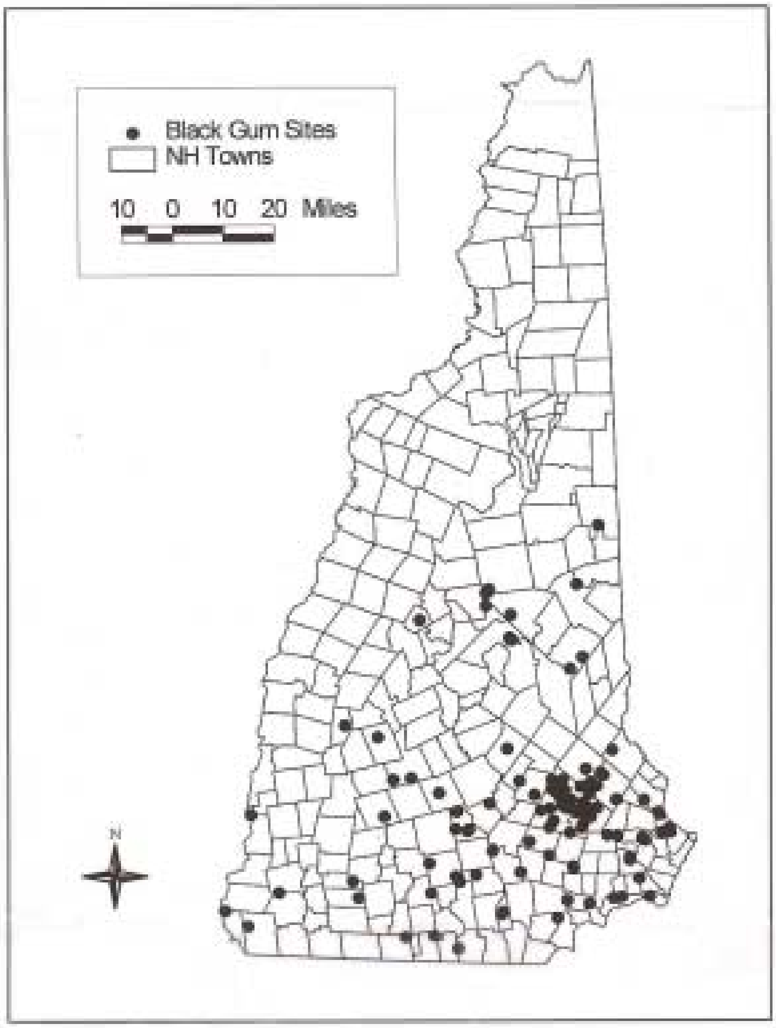


Figure 4. Distribution of all sites at which black gum trees were recorded. The sites on this map are distributed more broadly than the towns shown in Figure 3 because surveys were also made on public lands and some data were gathered from historical documents.

(1) **Basin swamps**: Black gum is most abundant and frequent in basin swamps, which are topographically defined basins with limited drainage and small watersheds that are isolated from perennial drainage ways and significant groundwater seepage. Usually much less than one square mile of drainage area flows into or through a basin. These basins are most often shallow depressions perched on hillside benches or concavities in glacial till soils. Black gum is also associated with basins in sand plain deposits, including swamp forests (such as Atlantic white cedar swamps) around kettle bogs or other acidic open peatlands with limited drainage. Most basin swamps have saturated to seasonally flooded peat soils and thus short periods of seasonal inundation.

(2) **Swamp- or marsh-borders**: Black gum is also found in low frequency and abundance in other wetland settings, including seepage swamps, streamside swamps, and freshwater marsh borders. In these locations, black gum is usually restricted to the upland border interface where the flood longevity and frequency are shorter. Some of the marshes with black gum along their

borders were created by beaver-flooding of former basin swamps. Black gum does occur sparingly in the interior portions of non-basin swamps, but is usually in low abundance in these settings. Black gum also occurs in a few upland sites adjacent to estuarine marshes along the coast, and in a basin swamp at the tidal interface that is apparently inundated by storm tides.

(3) **Floodplain forests and riverbanks**: Black gum has been documented as a minor associate of floodplain forests in the coastal region, including swamp white oak and red maple floodplains along small coastal rivers. These sites have fine alluvial soils that are regularly flooded but never inundated for long periods. Black gum has also been found in higher-energy environments of larger rivers that are also temporarily but more frequently flooded. These include stunted river channel thickets along the Connecticut River and tree-sized stands along the margins of open river channels of the Merrimack River.

(4) **Lake borders**: Black gum is occasional along pond and lake borders, another wet habitat with limited hydrologic fluctuations. Trees occur at the interface with sloped upland borders and on berms formed by ice-push. Black gum trees are abundant on some shoreline sections of these lakes. All of the northern-most black gum populations within the state (in Grafton, Carroll, and Belknap Counties) are associated with large lakes such as Newfound, Sunapee, Squam, and Winnipesaukee. These lakes may have a minor moderating effect on local climate that allows black gum to persist farther north than would otherwise be possible.

Vegetation of Black Gum Swamps

Based on the results of landscape analysis, NH Heritage surveyed examples of black gum swamps (particularly those in basin swamp settings, as described above) throughout their range in New Hampshire. We also compiled a database of occurrences of black gum trees to gain an understanding of the statewide distribution of habitats in which this species can occur. Figure 4 shows the distribution of all sites at which black gum trees were recorded, either by NH Heritage ecologists or by other individuals contacted during the landscape analysis process.

In order to characterize the variation in vegetation associated with black gum in the state, NH Heritage used classification and ordination techniques to analyze vegetation data from 32 releve plots. This subset of 32 plots (from a database of 46 releve plots) was selected to include plots from black gum swamps with *Sphagnum* moss identification to the species level. *Sphagnum* species are sensitive to variation in environmental variables such as hydroperiod and pH; therefore, identification of species within this group (often not performed because the group is taxonomically difficult) has contributed significantly to our understanding of the black gum swamps in which they occur.

Classification and ordination of black gum basin swamp vegetation data suggest that black gum swamps in New Hampshire fall into three principal variants. The definition of these variants was based on variation in plant species composition which relates well to vegetation structure (percentage of vegetation cover by trees, shrubs, herbs, and other vegetation strata) (see Figure 5 and Table 1). As described in Sperduto (1997), black gum and red maple dominated

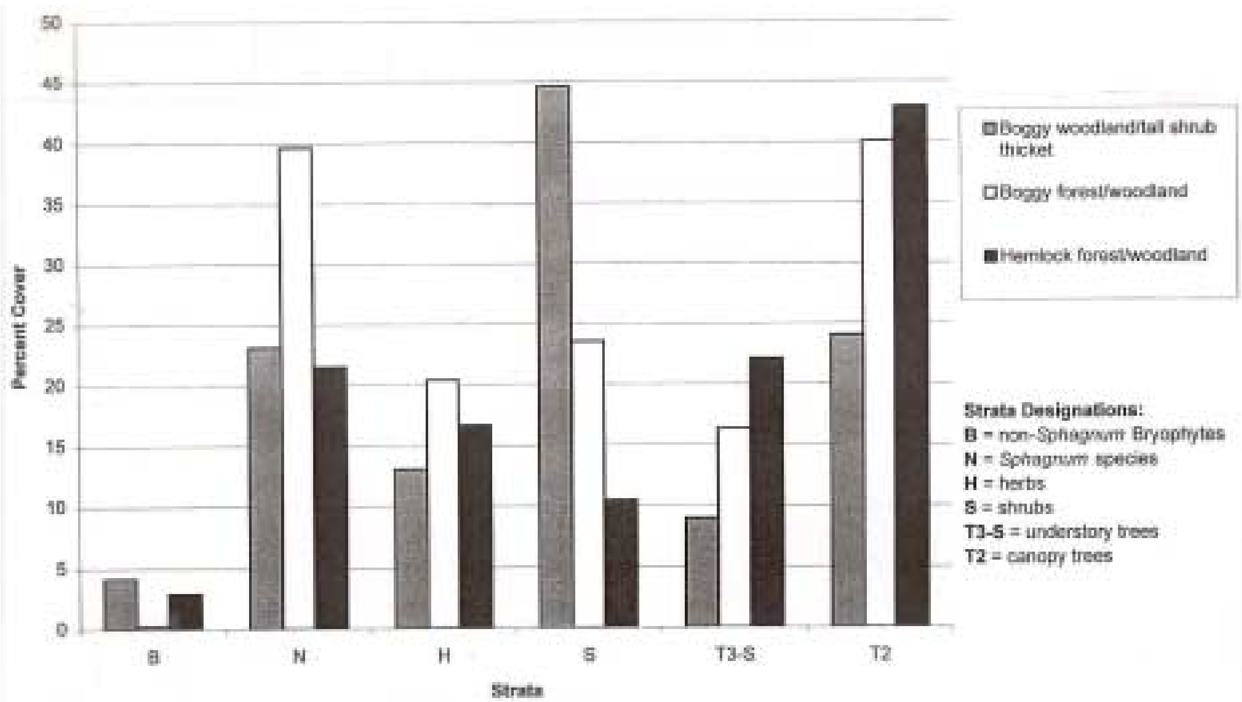


Figure 5. Average vegetation cover by strata for each black gum–red maple basin swamp variant.

Table 1. Environmental variables averaged for each black gum–red maple basin swamp variant.

Variable		Boggy woodland/tall shrub thicket variant	Boggy forest/ woodland variant	Hemlock forest/ woodland variant	Across All Variants
Depth of Organic Horizon (cm)	Avg	86.1	90.5	91.7	89.5
	SD	42.8	35.2	41.9	39.6
pH	Avg	4.5	4.1	4.5	4.4
	SD	0.3	0.5	0.4	0.4
Depth to H5 (cm)	Avg	13.4	14.7	8.9	11.8
	SD	10.2	13.1	9.6	10.6
Depth to H8 (cm)	Avg	21.8	31.7	40.3	32.1
	SD	13.6	19.1	32.9	25.6
Hummock Height (cm)	Avg	40.9	47.8	33.5	38.7
	SD	13.0	8.6	18.5	15.8
% Cover by *Sphagnum* Species on Hummocks	Avg	7.7	17.6	6.4	9.7
	SD	15.1	15.6	8.3	13.2
% Cover by *Sphagnum* Species in Hollows	Avg	18.0	33.8	12.6	19.9
	SD	19.3	17.3	18.7	19.9

the tree canopies of all three black gum–red maple basin swamp groups. In addition, the variants could be distinguished as follows:

1. boggy woodland/tall shrub thicket variant: woodlands or sparse, open-canopy woodlands with a generally high abundance of tall shrub species;
2. boggy forest/woodland variant: forests or woodlands with a significant component of *Picea rubens* (red spruce) and/or *Pinus strobus* (white pine) in the tree canopy or understory, with *Sphagnum* species typical of more oligotrophic conditions than found in other black gum habitats; and
3. hemlock forest/woodland variant: forests or woodlands often with a strong *Tsuga canadensis* (hemlock) component in the tree canopy and understory, with *Sphagnum* and herbaceous plant species indicative of slightly more minerotrophic conditions than in other black gum habitats.

Each of these variants is described fully below.

Appendix 6 provides a table of species by releve plot, which shows the three major divisions generated by the TWINSPAN classification process and the plant species that contributed to the distinctions among the three vegetation groups. Figure 6 overlays the three TWINSPAN-defined groups onto a DCA ordination of the 32 releve plots, which provides a visual picture of the variation in species composition among plots among the three groups. Plots shown on the ordination graph are plotted in “species space,” which is defined by the relative distances between plots based on their species composition and abundance. It is important to note that the distinctions described among variants were based on averages and trends for each group. Within each individual group, variability of species composition and structure among sample plots was frequently high, as shown in Figure 6.

Environmental data for the black gum swamp plots were also highly variable. Averaged by variant type, however, pH, average hummock height, depth of the organic soil horizon, and depth to von Post categories H5 and H8 were fairly consistent among groups (Table 2). The percent cover by *Sphagnum* species in hummocks and on hollows was slightly higher in the boggy forest/woodland variant, which contained *Sphagnum* species indicative of acidic, boggy conditions.

Analysis of plant species composition with respect to environmental variables for each sample plot, using CCA, did not clarify the composition-based distinctions between groups. The most likely explanations for this are: (1) the environmental data collected for the black gum plots may not have included the variables driving the floristic and structural variability in the vegetation; and (2) differences among black gum sites are minor compared to differences between black gum swamps and other swamp natural communities. Based on the floristic groupings evident in the vegetation data, it is possible that variables closely tied to hydroperiod and minerotrophic level would help to explain the variability in the vegetation. The poor correspondence between the TWINSPAN-defined variants and the environmental gradients depicted through CCA may also result in part from the relatively small sample size of black gum plots with environmental data (McCune and Mefford 1999).

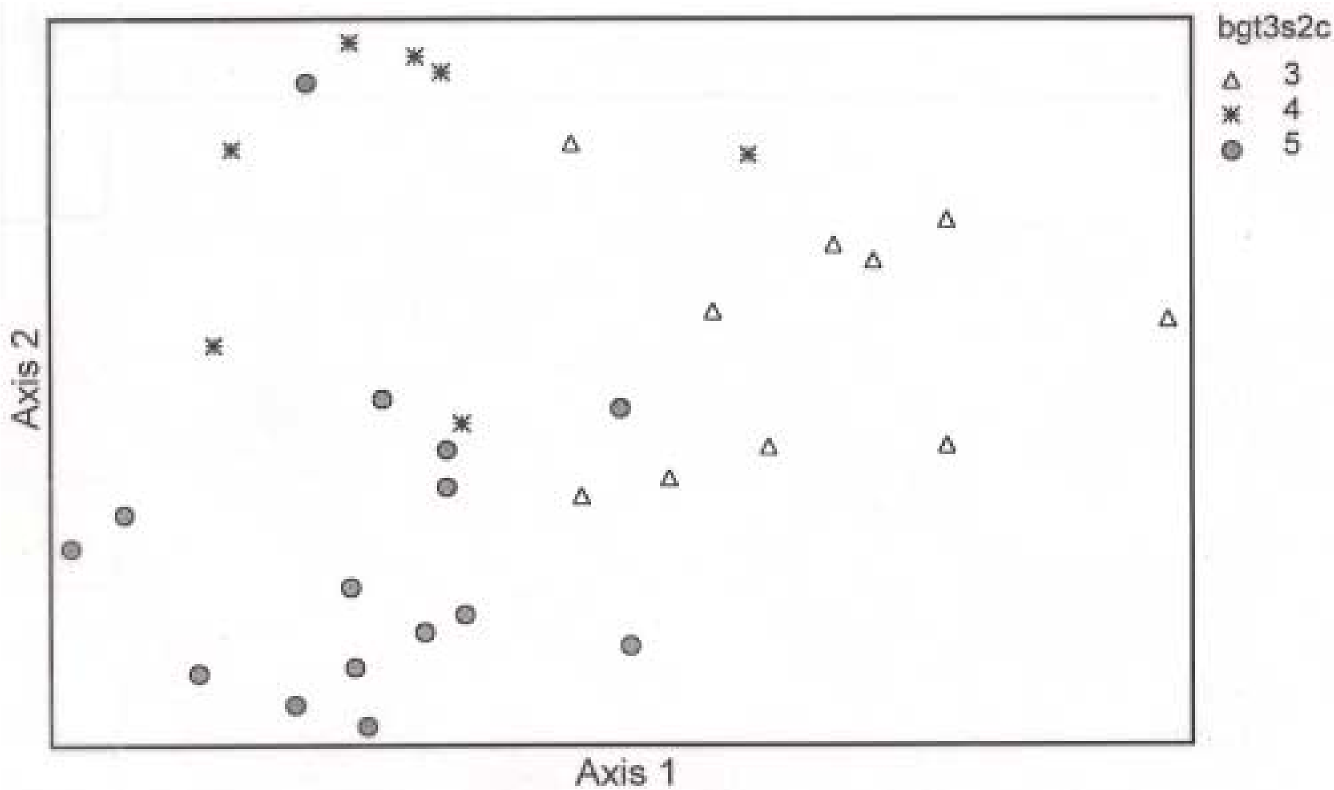


Figure 6. DCA showing the distribution of plots within each black gum–red maple basin swamp variant. Plots are located in "species space," which is defined by the relative distances between plots based on their species composition and abundance. Codes: Δ = boggy woodland/tall shrub thicket variant; ✳ = boggy forest/woodland variant; ● = hemlock forest/woodland variant.

Table 2. Percent cover by strata for each black gum–red maple basin swamp variant.

Strata	Strata Code		Boggy woodland/tall shrub thicket variant	Boggy forest/ woodland variant	Hemlock forest/ woodland variant	Across All Variants
Tree Canopy	T2	Avg	24.0	35.4	42.4	35.14
		SD	14.6	11.3	16.0	16.39
Tree Understory	T3-S	Avg	8.9	12.8	22.6	16.18
		SD	4.7	6.4	13.8	11.82
Shrubs	S	Avg	44.6	25.5	10.9	24.61
		SD	20.4	24.3	8.9	22.15
Vines	V	Avg	0.0	0.0	0.1	0.03
		SD	0.0	0.0	0.2	0.12
Herbs	H	Avg	13.1	20.3	17.9	16.91
		SD	14.4	12.3	9.6	11.77
Sphagnum spp.	N	Avg	23.1	50.4	20.3	27.76
		SD	25.2	24.5	25.1	27.10
Bryophytes (non-*Sphagnum*)	B	Avg	4.1	0.0	2.5	2.48
		SD	7.5	0.0	4.6	5.33
Total Number of Plots			10	7	15	32

As described above, most of the black gum-dominated swamps in which plot data were collected can be described, from a hydrological perspective, as basin swamps. Basin swamps typically occur in topographically defined basins with stagnant or poor drainage, little seepage or alluvial influence, and saturated and/or seasonally flooded hydrologic regimes. Precipitation and seasonal subsurface runoff from small surrounding watersheds are the primary water sources, and evapotranspiration is a primary source of seasonal water table fluctuation. Consequently, nutrient poor and acidic conditions prevail. Organic muck and peat soils typically accumulate due to the lack of aeration and cold, acidic conditions. These conditions distinguish basin swamps from forested wetlands in which other sources of water predominate, including seepage swamps, streamside/lakeside swamps, mixed hydrology swamps, and floodplain forests (Sperduto 1997).

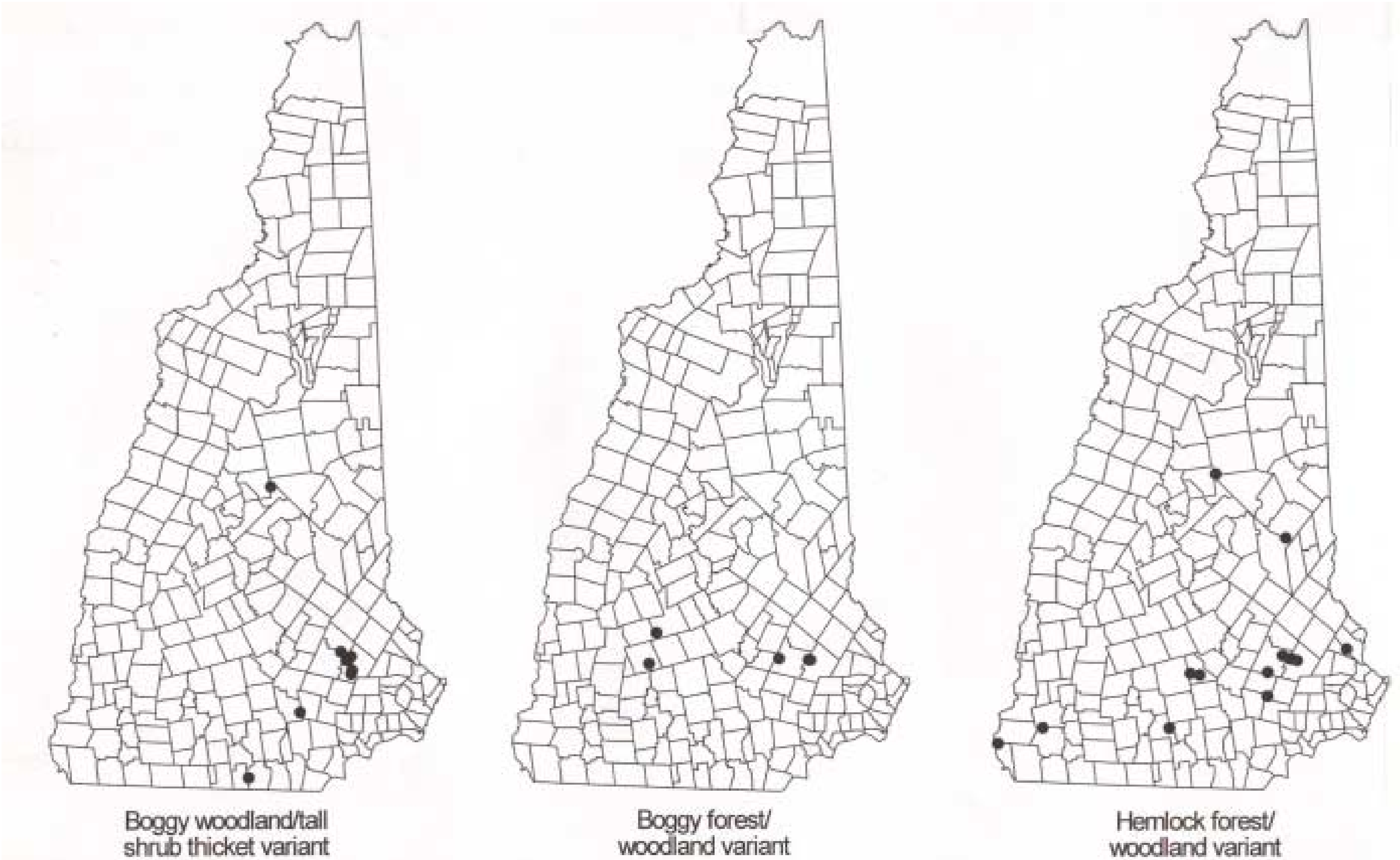
Black Gum–Red Maple Basin Swamp

Nyssa sylvatica – Acer rubrum/*Ilex verticillata*/*Sphagnum*

GENERAL DESCRIPTION: Black gum–red maple basin swamps are very similar in vegetation, soils, and hydrology to red maple/Sphagnum saturated basin swamps (Sperduto 1997). A principal distinction between these communities is the codominance of black gum with red maple in the canopy of black gum–red maple basin swamps. These swamps typically occur in perched upland till basins with watersheds smaller than one square mile. No vascular species are uniquely diagnostic of black gum swamps compared to red maple basin swamps, but species typical of acidic, relatively stagnant conditions are prevalent. Black gum–red maple basin swamps are highly variable in structure and composition, likely resulting in part from variability in hydroperiod and nutrient availability. These swamps vary from forest (greater than 60% tree cover) to sparse woodland (10 to 25% tree cover), with corresponding increases in the density of the shrub layer in woodland and sparse woodland examples. Historical logging activities may also have influenced the structure and composition of these swamps, and additional research on stand history is needed to clarify the relationships between land use history and current vegetation.

SOILS/GEOLOGY/HYDROLOGY: Soils are typically organic in nature, including acidic, nutrient-poor, very poorly drained histosols (deep peat or muck) or poorly to very poorly drained histic epipedons. Peat is typically well decomposed near the surface, and pHs average approximately 4.4 (range: 3.7–5.3). Hummocks are well developed and average approximately 0.4 m high. As in other basin swamps, black gum–red maple basin swamps have relatively little evidence of seepage or surface water flow. Examples in lakeside settings may be influenced somewhat by surface flow, but water sources are generally restricted to precipitation, seasonal subsurface flow, and ephemeral runoff from surrounding uplands. Many of these swamps have stagnant outlet streams but no perennial inlets or streams running through them; others have neither inlets nor outlets.

Figure 7. Distribution of black gum–red maple basin swamp variants.



CHARACTERISTIC VEGETATION: In the majority of black gum–red maple basin swamps, *Nyssa sylvatica* (black gum) and *Acer rubrum* (red maple) dominate the tree canopy, with varying but smaller contributions by other hardwood and softwood species. *Vaccinium corymbosum* (highbush blueberry) and *Ilex verticillata* (winterberry) are typically the primary dominants in the shrub layer, with a variable component of other tall and medium-height shrub species. *Osmunda cinnamomea* (cinnamon fern) is generally abundant in the herbaceous layer, which consists of a combination of some species indicative of moist, acidic conditions (particularly in hollows) and others characteristic of drier habitats (typically on hummocks). *Sphagnum* mosses often form a patchy to dense layer, particularly in hollows and on the lower sides of hummocks. The species composition of three variants is described in detail below (see Figure 7 for distribution maps).

BOGGY WOODLAND/TALL SHRUB THICKET VARIANT
Nyssa sylvatica – Acer rubrum/Vaccinium corymbosum – Ilex verticillata

This variant predominantly consists of woodlands or sparse woodlands. A mixture of *Nyssa sylvatica* (black gum) and *Acer rubrum* (red maple) dominates in the tree canopy; softwood species, such as *Picea rubens* (red spruce) and *Tsuga canadensis* (hemlock), may be present in low abundance in the canopy but are more likely to occur in the understory. The tall shrub layer is correspondingly moderate to very dense, the herbaceous layer is sparse to moderate, and *Sphagnum* mosses form a moderate to dense, sometimes patchy ground cover.

The shrub layer is generally dominated by tall shrub species. *Vaccinium corymbosum* (highbush blueberry) and *Ilex verticillata* (winterberry) typically codominate, but *Nemopanthus mucronatus* (mountain holly) may also be abundant. Other shrub species may include *Ilex laevigata* (smooth winterberry), *Cephalanthus occidentalis* (buttonbush), *Aronia arbutifolia* (red chokeberry), and the short shrub species *Kalmia angustifolia* (sheep laurel).

While the herbaceous layer is generally not dense, *Carex canescens* (silvery sedge), *Carex trisperma* var. *trisperma* (three-seeded sedge), and *Osmunda cinnamomea* (cinnamon fern) are frequently present in low to moderate abundance. Relatively frequent species include *Coptis trifolia* var. *groenlandica* (goldthread), *Osmunda regalis* var. *spectabilis* (royal fern), *Lysimachia terrestris* (swamp candles), *Lycopus uniflorus* (common water horehound), and *Dulichium arundinaceum* (three-way sedge). The upland species *Trientalis borealis* (starflower) and *Aralia nudicaulis* (wild sarsaparilla) occur frequently but in low abundance on drier hummocks.

Sphagnum mosses occur both on hummocks and in hollows but predominate in the wetter hollows of this variant. *Sphagnum magellanicum* is the most frequent and abundant *Sphagnum* species. *S. torreyanum,* a predominantly aquatic, coastal plain species, is locally dominant in hollows.

Sites of this variant type appear to be wetter on average than other examples, based on the frequency of hydrophytic species such as *Sphagnum torreyanum* and *Carex canescens*. Lakeside occurrences of black gum–red maple basin swamp typically fall within this variant. The woodland/sparse woodland structure characteristic of these swamps may result in part from a longer hydroperiod than in other swamps; however, logging history should also be investigated for its potential influence on composition and structure, as some apparent examples may be successional to a more forested state.

Figure 8. (TOP) A 562 year old black gum tree in Rockingham County, NH. Note the deeply furrowed bark on the lower side of the leaning tree.

Figure 9. (BOTTOM) Cross section of a 400+ year old black gum tree killed by beaver flooding in the Deerfield Black Gum Swamp.

BOGGY FOREST/WOODLAND VARIANT

Nyssa sylvatica – Acer rubrum – Picea rubens – Pinus strobus/Sphagnum

The forest or woodland tree canopy of this variant is dominated by a variable mixture of *Nyssa sylvatica* (black gum) and *Acer rubrum* (red maple), frequently with a component of *Picea rubens* (red spruce) and/or *Pinus strobus* (white pine) in the canopy and/or subcanopy. *Tsuga canadensis* (hemlock) and *Betula alleghaniensis* (yellow birch) are typically restricted to the understory. The shrub and herbaceous layers are of moderate density on average but are highly variable, and *Sphagnum* mosses are more abundant on average than in other black gum swamps (Figure 5). The *Sphagnum* species that occur in this variant tend to be indicative of more acidic, nutrient-poor conditions than those of the hemlock forest/woodland variant, giving examples a more boggy character.

In the shrub layer, *Vaccinium corymbosum* (highbush blueberry) and *Ilex verticillata* (winterberry) dominate; total cover ranges from low to high, but abundance of these species is lower on average than that of the boggy woodland/tall shrub thicket variant. *Viburnum nudum* var. *cassinoides* (witherod) is typically present in low abundance, as are the short shrub species *Gaultheria procumbens* (wintergreen), *Gaultheria hispidula* (creeping snowberry), and *Cornus canadensis* (bunchberry). Other relatively frequent shrub species include *Nemopanthus mucronatus* (mountain holly), *Lyonia ligustrina* (male-berry), and *Kalmia angustifolia* (sheep laurel). *Ilex laevigata* (smooth winterberry) and *Cephalanthus occidentalis* (buttonbush) typically are not present.

Density of the herbaceous layer is moderate on average but variable. *Osmunda cinnamomea* (cinnamon fern) typically dominates, while *Coptis trifolia* var. *groenlandica* (goldthread) and *Carex trisperma* var. *trisperma* (three-seeded sedge) are generally present in low abundance. *Carex canescens* (silvery sedge) may occur in low abundance in wetter hollows and *Trientalis borealis* (starflower) on drier hummocks. *Sarracenia purpurea* (pitcher-plant) occurs only occasionally, but its presence helps distinguish this variant from the hemlock forest/woodland variant described below.

Sphagnum mosses typically form a relatively dense carpet dominated by one or more species, including *Sphagnum fallax*, *S. angustifolium*, and/or *S. magellanicum*. *S. magellanicum* tends to be a generalist species of many acidic, somewhat open, northern peatlands. *S. angustifolium* is characteristic of open or sparsely wooded oligotrophic to minerotrophic peatlands, while *S. fallax* is indicative of oligotrophic to weakly minerotrophic conditions and is characteristic of open or wooded peatlands.

HEMLOCK FOREST/WOODLAND VARIANT

Nyssa sylvatica – Acer rubrum – Tsuga canadensis

This variant predominantly consists of forests/woodlands dominated by a mixture of *Nyssa sylvatica* (black gum) and *Acer rubrum* (red maple), often with a strong *Tsuga canadensis* (hemlock) component in the tree canopy and/or subcanopy. *Betula alleghaniensis* (yellow birch), and *Pinus strobus* (white pine) are typical in the understory. While variable, the shrub layer is sparser on average in this variant, and the herbaceous and

Sphagnum layers are generally of moderate density (Figure 5). The *Sphagnum* species that occur in this variant suggest slightly more minerotrophic conditions than are present in other black gum swamps (Andrus 1980).

In the shrub layer, *Vaccinium corymbosum* (highbush blueberry) and *Ilex verticillata* (winterberry) dominate as in the other variants, but total cover is on average fairly low to moderate. Other shrub species that occur with some frequency in relatively low abundance include *Nemopanthus mucronatus* (mountain holly), *Aronia arbutifolia* (red chokeberry), and the short shrub species *Gaultheria procumbens* (wintergreen).

Total cover in the herbaceous layer generally ranges from low to moderate. *Osmunda cinnamomea* (cinnamon fern) is generally abundant, and *Coptis trifolia* var. *groenlandica* (goldthread) is typically present in low to moderate abundance. Species that occur frequently in low abundance include royal fern, *Carex trisperma* var. *trisperma* (three-seeded sedge), *Aralia nudicaulis* (wild sarsaparilla), and *Maianthemum canadense* (Canada mayflower).

Total cover by bryophyte species is variable but typically ranges from low to moderate. Each of the several species of *Sphagnum* moss in this variant occurs with low frequency; considered as a group, however, several of these species are indicative of slightly more minerotrophic conditions than are present in the other black gum swamps. These minerotrophic indicator species (Andrus 1980) include *Sphagnum flexuosum*, *S. affine*, *S. centrale*, *S. henryense*, *S. fimbriatum*, *S. palustre*, and *S. recurvum*. *S. fallax* tends to occur in weakly minerotrophic

Figure 10. Aerial view of the Deerfield Black Gum Swamp complex. The large wetland without leaves shows black gums killed in 1990 after beavers flooded the wetland. Other black gum pockets are evident by their red fall foliage.

conditions. Other *Sphagnum* species in this variant include *S. angustifolium*, *S. magellanicum*, *S. torreyanum*, and *S. cuspidatum*. In addition to the *Sphagnum* species, other bryophytes are also more frequent.

Moisture conditions appear to be highly variable. Conditions range from relatively dry, with a high frequency of *Mitchella repens* (partridge-berry), to fairly wet, characterized by occurrences of species such as *Carex canescens* (silvery sedge), *Thelypteris palustris* var. *pubescens* (marsh fern), and *Glyceria canadensis* (rattlesnake manna-grass). *Sphagnum* species indicative of slightly more minerotrophic conditions are present across this range of moisture levels. Additional minerotrophic indicators that occur in this variant include *Osmunda regalis* var. *spectabilis* (royal fern – relatively frequent), *Chelone glabra* (white turtlehead – occasional), and *Fraxinus nigra* (black ash – occasional).

MOUNTAIN LAUREL VARIANT
Nyssa sylvatica – Acer rubrum – Kalmia latifolia

Three plots from the southwestern portion of the state contained a significant amount of *Kalmia latifolia* (mountain laurel); however, these plots did not emerge as a distinct group during the TWINSPAN analysis of the releve plot data. The dominance of mountain laurel in these swamps, in additional examples in the state that were not sampled, and in other swamps farther south in Massachusetts (Zebryk 1990), may indicate the existence of a distinct floristic association worthy of further research.

Stand Structure

As was true for other aspects of the black gum basin swamp plots, stand structure varied considerably among plots both within and between variant types. Averaged by variant, the principal structural difference among groups was the distinction between woodland/tall shrub thicket and forest/woodland plots. While variability among plots was high, average stem density in the smaller diameter classes was lower in the subset of plots with a correspondingly low total canopy cover and high cover by tall shrub species (see Figures 11, 12, 13, and 5; Appendix 7). Average basal area in the smaller diameter classes was also lower in the boggy woodland/tall shrub thicket variant than in the more forested variants; however, average basal area in the middle diameter classes was generally comparable among the three variants (Figure 15, 16, 17, and 18; Appendix 7). Trees greater than 24 in. in diameter were not present in the boggy woodland/tall shrub thicket plots.

Also notable among variants, the stem density for black gum in woodland/tall shrub thicket plots was comparable to that of forested plots (Figures 11, 12, and 13). Differences in overall stem density among groups arose primarily from shifts in abundance of canopy species other than black gum itself. It is possible that the relatively consistent stem density for black gum across these groups results in part from environmental factors and in part from historical logging activities, which may have selected large softwoods and left black gum trees intact, although field signs of logging were not present in most plots. Research on individual stand histories

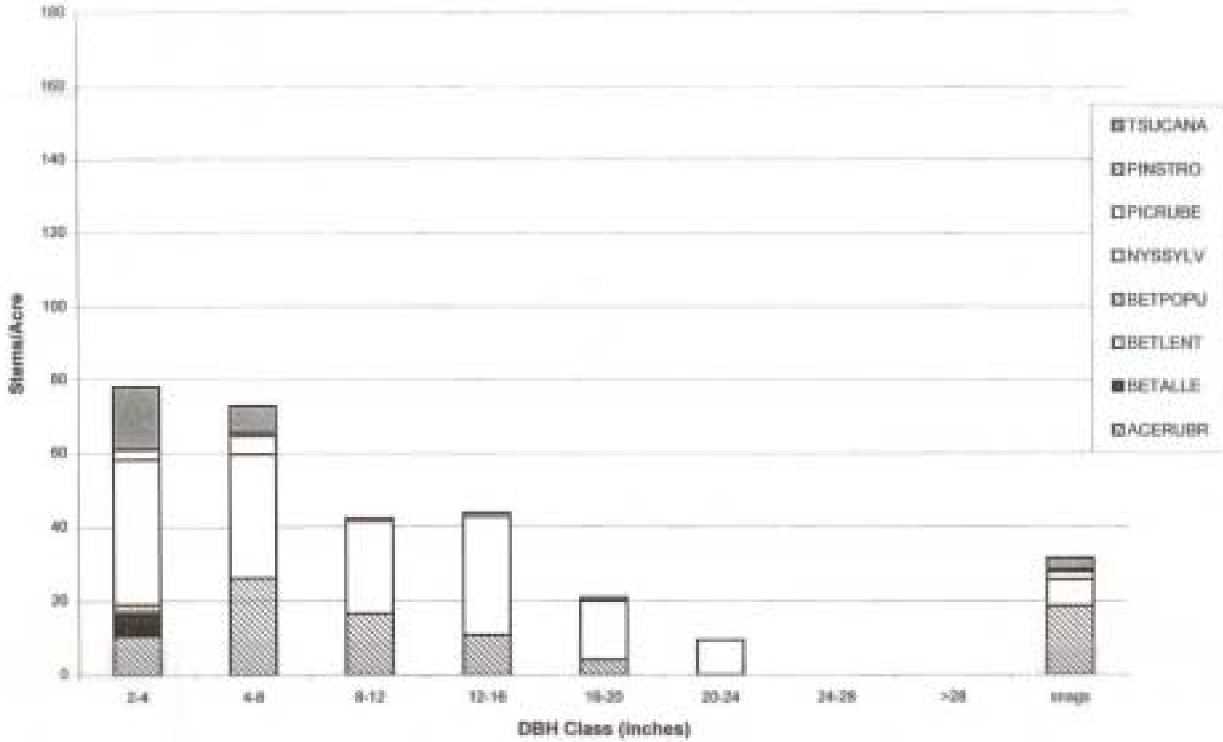


Figure 11. Average stem density by DBH class and species for the boggy woodland/tall shrub thicket variant. See Appendix 5 for a complete list of species codes.

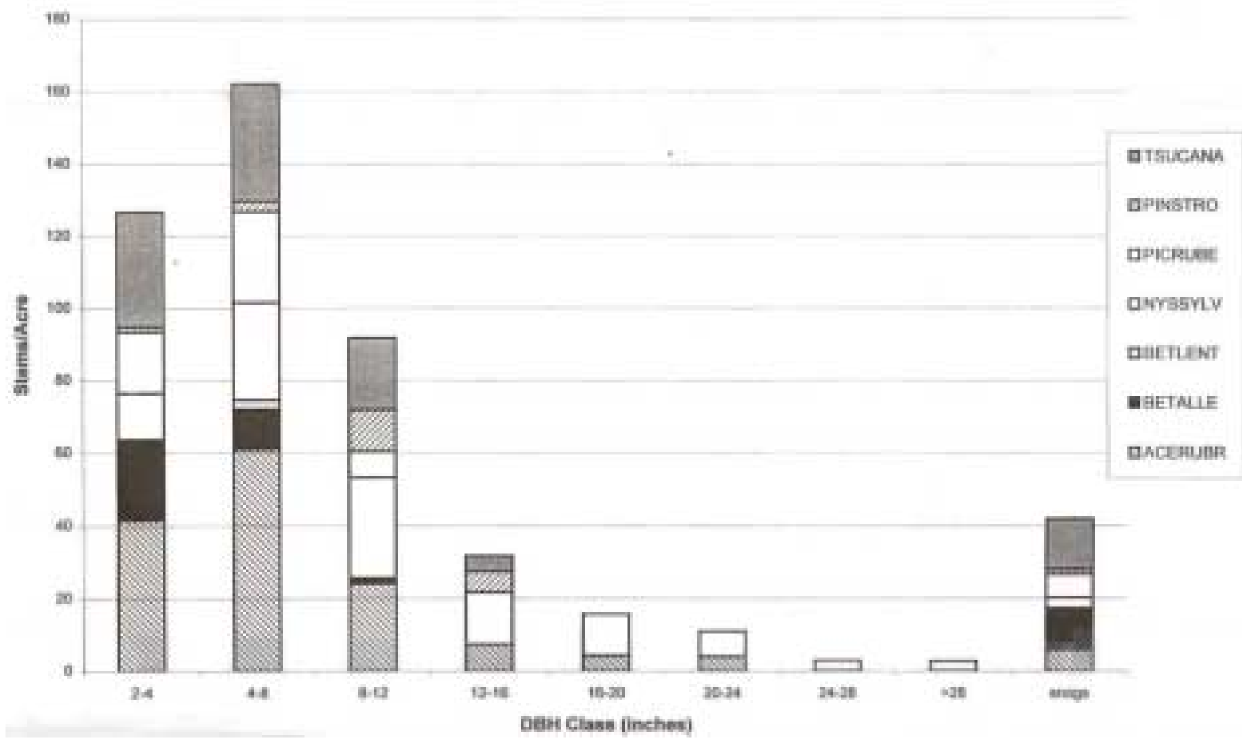


Figure 12. Average stem density by DBH class and species for the boggy forest/woodland variant. See Appendix 5 for a complete list of species codes.

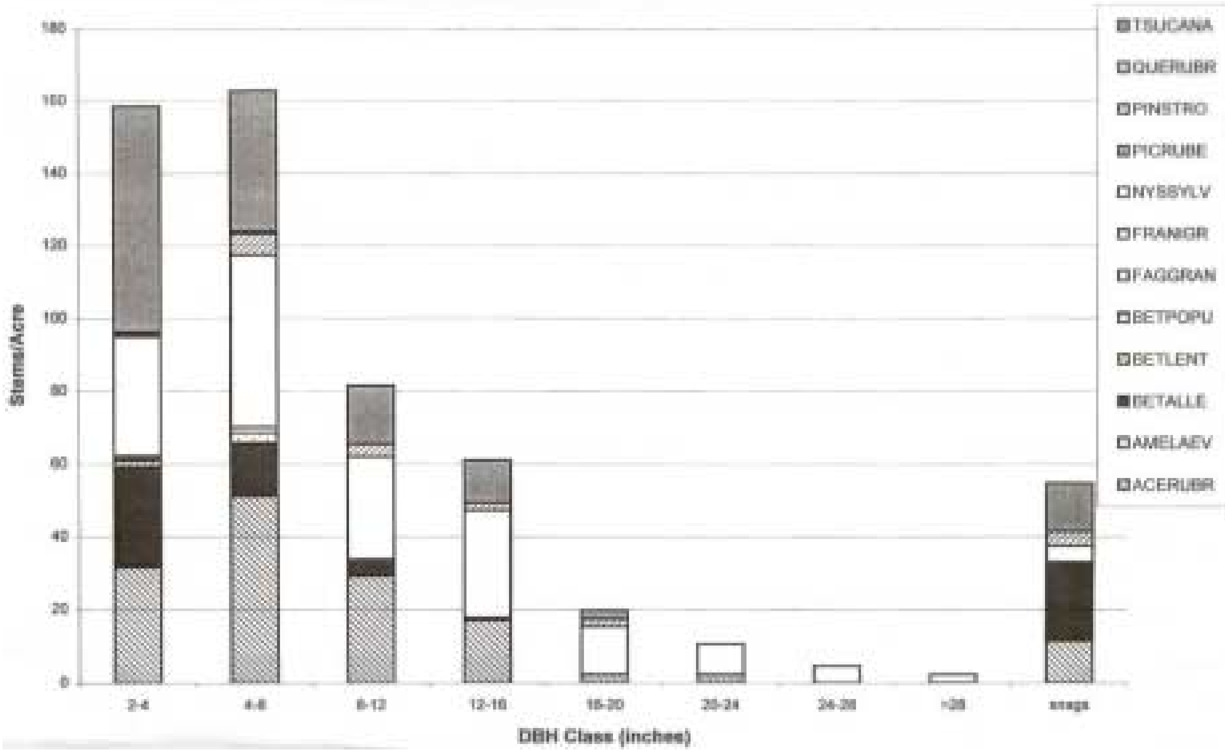


Figure 13. Average stem density by DBH class and species for the hemlock forest/woodland variant. See Appendix 5 for a complete list of species codes.

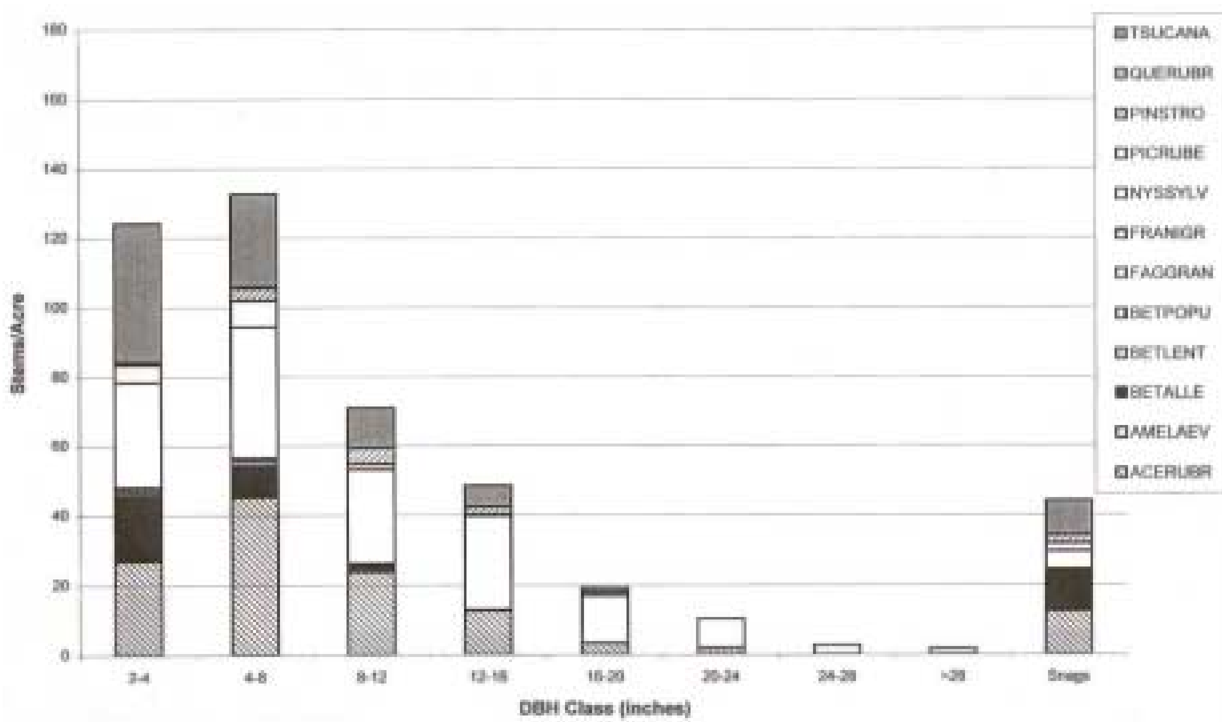


Figure 14. Average stem density by DBH class and species across black gum–red maple basin swamp plots. See Appendix 5 for a complete list of species codes.

would be needed to clarify the potential effects of logging on the composition and structure of black gum swamp communities.

On average, stem density in black gum basin swamp plots decreased with increasing size class; typically, stands had many small trees and fewer large trees. Whether considered by plot, by variant, or across all plots sampled, however, the stem density of black gum itself typically was not distributed according to a typical “J”-shaped frequency histogram of uneven-aged stands, in which stem density decreases rapidly with increasing size class. Averaged both by variant and across variants, stem density of black gum remained fairly consistent through the smaller size classes (Figures 11, 12, 13, and 14). Also across variants, for trees greater than 16 in. in diameter, average stem density of black gum appeared to decrease considerably but less rapidly than for other species. For some individual plots, the frequency distributions both of black gum and of other species showed evidence of distinct cohorts in middle size classes and the absence of cohorts in small size classes, resulting in considerable structural variability both within and among types of black gum swamps.

Although the stem density of black gum often was not distributed according to the typical “J”-shaped distribution of uneven-aged stands, it is important to note that many size classes were represented in most plots. This suggests a diverse size structure in black gum swamps even at the fine scale of 20 m x 20 m plots.

The variability in structure among stands may suggest varied natural disturbance histories, given that very few stands had indicators of logging or other human disturbance activity. It is also possible that black gum stands exhibit highly varied structural patterns over time because of the longevity of black gum trees and the comparatively short life spans of most other tree species. Because black gum trees are long-lived and clonal in nature, they may not always follow the reproductive and growth patterns typical of other species.

Dendrochronology and Age Composition

NORTH AMERICAN DENDROECOLOGICAL FIELDWEEK

In 1996, NH Heritage helped sponsor the annual North American Dendroecological Fieldweek. One of the Fieldweek’s study groups studied a black gum swamp in Rockingham County to obtain more accurate age estimates of a population of ancient black gum and to determine if a tree ring chronology could be linked to environmental and climatic patterns over the course of centuries. This work led to the discovery of some of the oldest trees in New England and New York, and perhaps some of the oldest hardwood trees in the continent.

Preliminary results indicate that there is a good potential link between the growth pattern of black gum (recorded in tree rings) and climate patterns (July temperature), although these results need to be substantiated by expanding the analysis to include additional tree cores, including tree core data from other sites. These types of data not only have relevance to the conservation of black gum swamps, but they open a scientific window into the nature of environmental change over nearly 600 years, a time scale that exceeds those from any other trees currently known in New England.

AGE AND AGE STRUCTURE OF BLACK GUM

Black gum is apparently the longest-lived broadleaf deciduous tree in North America. We have documented six sites in New Hampshire that have black gum trees older than 500 years of age (see Figure 8), with the oldest individual at one of these sites exceeding 679 years. We counted tree rings in cores taken from one to five trees at each of 20 sites. Cores from 28 trees were counted from one other site where beavers had recently killed all of the black gum in a large, 20-acre basin. Nineteen of these 21 sites contain trees that exceed 200 years of age, 13 contain trees more than 300 years old, and eight contain trees that exceed 400 years. Records of cores taken in black gum swamps by NH Heritage are included in Appendix 4. Since black gum is clonal, it is quite possible that total ages of genetic individuals are much greater. It is conceivable that some individuals exceed 1,000 years of age.

For any given species, weak relationships between tree age and DBH are probably more common than not because of variation in growing conditions and competition between individuals. However, there appears to be a good relationship in black gum based on cores taken from basin swamp habitats in New Hampshire. We ran a simple linear regression between DBH and ring count at DBH based on cores from 62 trees (R2 = 0.71; Figure 19). No cores were used from trees with rotten centers or that were not clearly near the pith (all were within approximately 15 years of the pith). Since some of the tree cores did not intersect with the pith, we ran the same regression using only cores that came within an estimated 5 years of the pith (n = 29; R2 = 0.70) and on cores that were within 5-15 years of the pith (n = 33; R2 = 0.56; Figure 20). This revealed that using cores that were off by more than 5 years to the pith did affect the proportion of variance explained by the resulting regression, but did not introduce a systematic bias. This is depicted by the similar slopes and positions of the two least-squares regression lines (Figure 20). Alternative regressions could be developed based on estimates of total age to pith by extrapolation of growth rate in inner-most rings and/or by estimating total age of the tree including years to achieve breast height. While there is wide variance in ages among trees over 25 in. DBH, no trees of this size are less than 225 years old and only two are less than 300 years old. Further, no trees larger than 20 in. were less than 225 years old. Most cores exhibited extended periods of slow to extremely slow growth, and periods of release were occasional but generally not maintained for long periods.

There are several indications that multi-aged structures may be more frequent in black gum stands than even-aged structures. First, while the frequency (number of trees) and basal area per acre distribution of black gum is variable between plots, the presence of numerous size classes within any given plot is very common. For example, 28 of 33 plots (85%) had trees in four or more of the 4-in. size classes, and 19 (58%) had five or six size classes present (see Appendix 8). This suggests that fine scale variation in size class distribution is common. Further, since there is a reasonably good general relationship between DBH and age, the varied size structure of most stands suggests that an uneven-aged structure is common at a fine scale within black gum stands. While the age and age structure of other tree species in black gum swamps has not been well established, all have considerably shorter longevity than black gum and are therefore likely

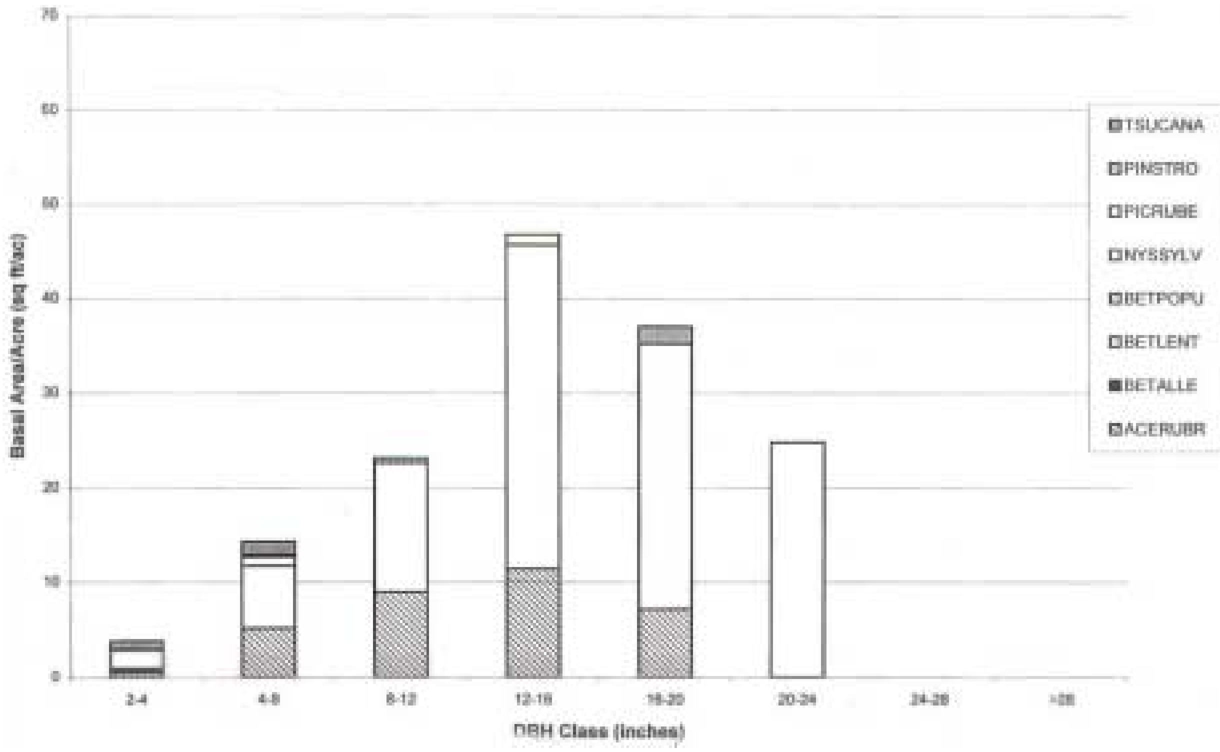


Figure 15. Average basal area by DBH class and species for the boggy woodland/tall shrub thicket variant. See Appendix 5 for a complete list of species codes.

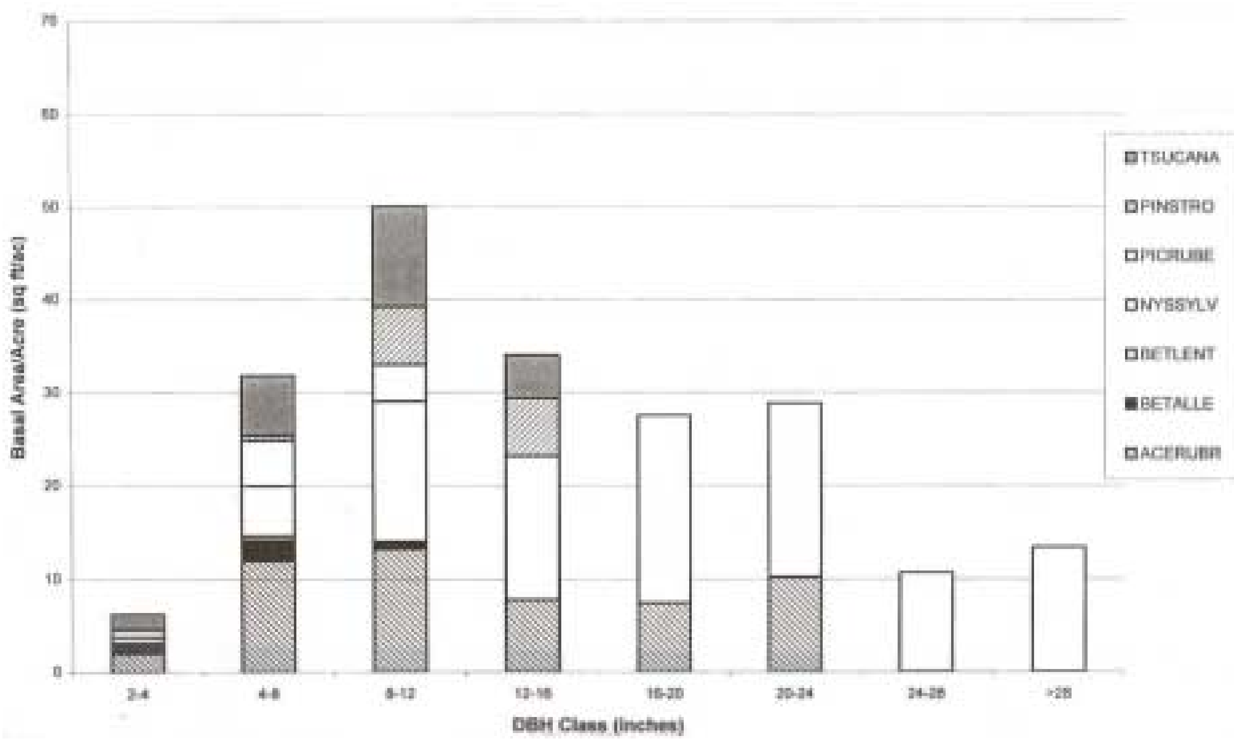


Figure 16. Average basal area by DBH class and species for the boggy forest/woodland variant. See Appendix 5 for a complete list of species codes.

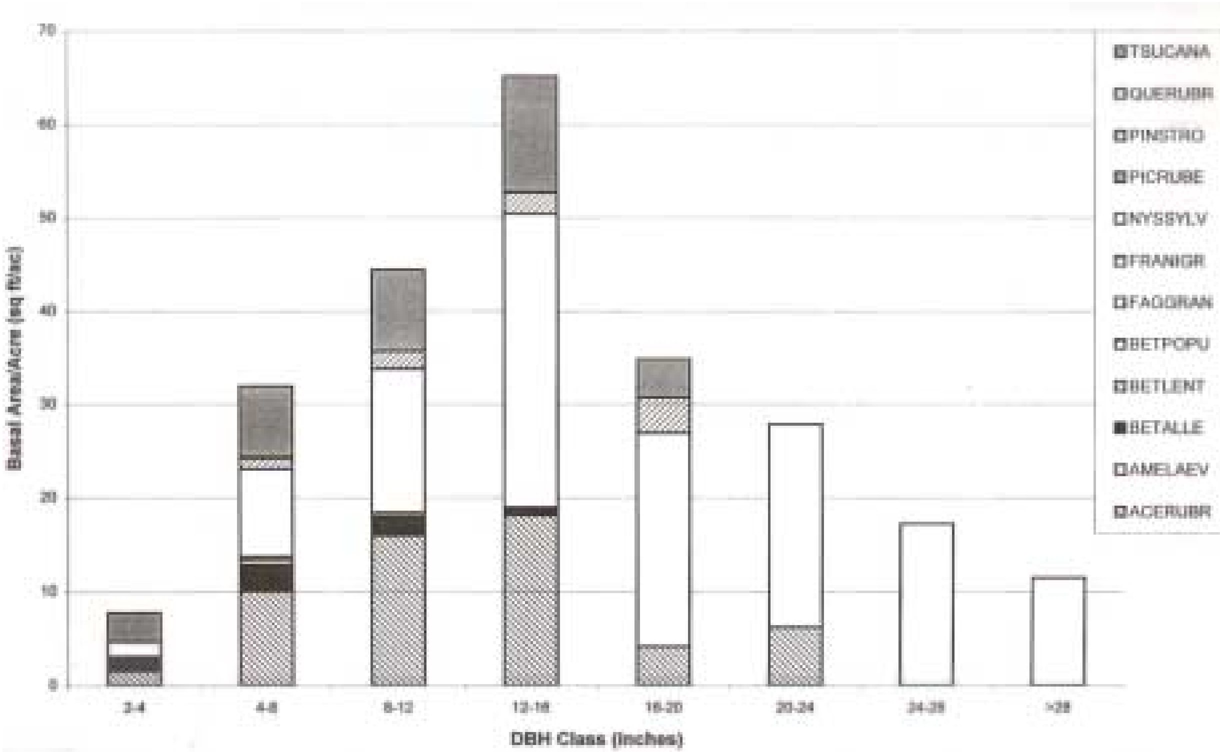


Figure 17. Average basal area by DBH class and species for the hemlock forest/woodland variant. See Appendix 5 for a complete list of species codes.

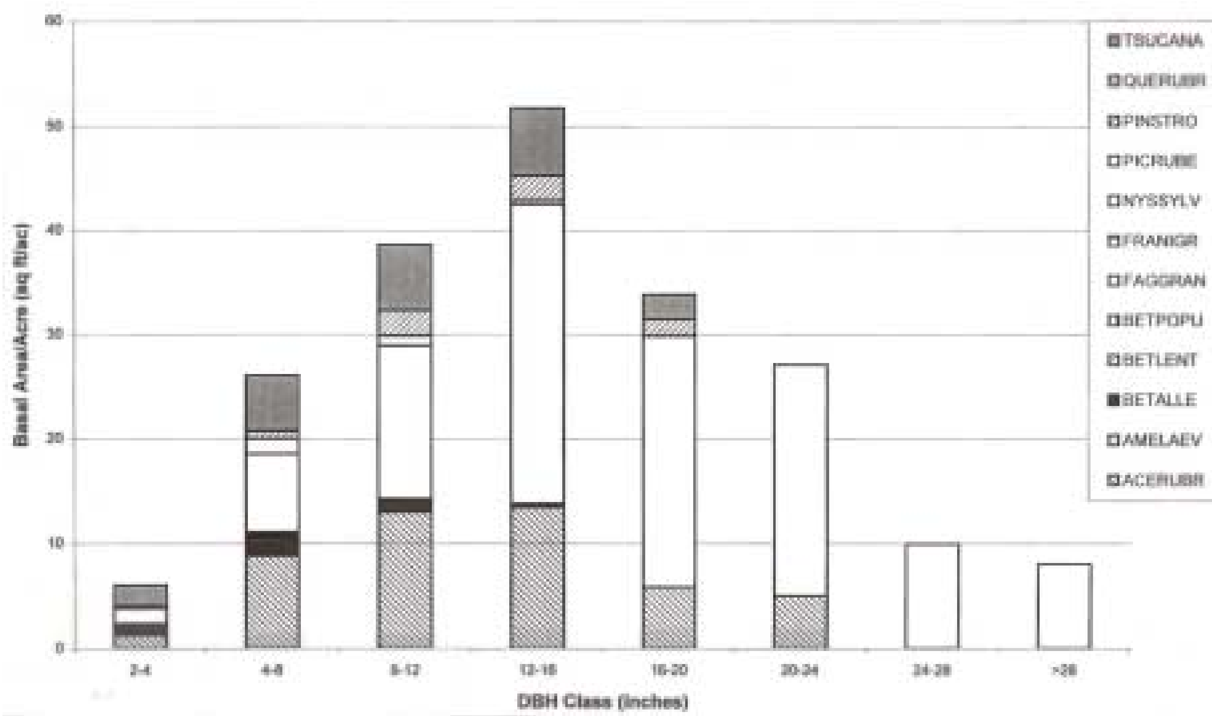


Figure 18. Average basal area by DBH class and species across black gum–red maple basin swamp plots. See Appendix 5 for a complete list of species codes.

to produce two to many generations for each black gum generation. Hemlock can achieve 500 years of age but, to our knowledge, ages approaching this limit have never been recorded in a swamp setting. Second, widely disparate ages were common based on sites where three or more trees were cored. Third, a more detailed evaluation of the age and size structure of a single black gum swamp (detailed below) indicates a multi-aged and multi-size class stand in an old growth condition.

STAND HISTORY OF DEERFIELD BLACK GUM SWAMP

The largest basin at Deerfield Black Gum Swamp (20 acres) dominated by black gum and red maple contained hundreds of healthy black gum trees, including many large stems, in 1989 and previously (pers. obs. and Phil Auger, pers. obs.). Shortly thereafter, beavers girdled many of the trees and flooded the basin (see Figure 10). A dendroecological study conducted in 1996 as part of the North American Dendroecological Field Week (Berg *et al*. 1996) placed the death of trees to 1990 at the west end of the basin near the beaver dam outlet (see Figure 9). Trees closer to the eastern end of the swamp survived until 1993. In March 1993, 23 black gum, five red maple, three hemlock, and one spruce were cored from an approximately six-acre area towards the west end of the swamp near the beaver dam. We primarily cored larger black gum (19-29 in. DBH), but cored a few trees in the 5-10 in. range. Qualitative observations indicated that this area was similar to the majority of the 20-acre swamp in terms of size and abundance of black gum. Two 5-BAF prism plots were taken in the southeast portion of this coring area at randomized locations (Figure 22). A third prism plot was taken from an approximately one-acre section of the swamp dominated by red maple northwest of and beyond the coring area to contrast with the black gum dominated area (Figure 22). Some of the trees had rotten centers or uncountable core sections, but 16 black gum cores were readable.

Trees over 20 in. DBH had pith ages (at DBH) ranging from 352–533 years in 1990 when they died, indicating pith-dates ranging from 1638– 1457 A.D. (Figure 21). Actual germination dates probably ranged from 6-15 years prior to these dates, depending on the time it took each tree to attain breast height. The widely varying pith-dates and lack of a smaller number of more distinct age cohorts suggest that black gum are tolerant of large-scale disturbance events (e.g., hurricanes, major ice storms).

DISCUSSION OF AGE STRUCTURE

Multi-age stand structure appears to be a common feature of many black gum swamps in New Hampshire. This is indicated by: extensive coring from a single old growth site; more limited coring from numerous other sites; and a varied age structure implied by the wide variation in stand size class within plots and the good general relationship between tree size and age. While the approximate correspondence of some pith dates suggests that age cohorts probably do exist, most sites have more than the one or two age cohorts that would be expected if large-scale, stand-replacing disturbances were controlling age distribution. This suggests that black gum populations in New Hampshire basin swamps may be structured more by single-tree (gap-phase) replacement dynamics than by disturbance events that affect the entire black gum population. The abundance of many old trees at many New Hampshire sites indicates that black gum trees are able to withstand many centuries of hurricanes and ice storms to a greater extent than any other upland or swamp forest species. Further, the development and decline of associated tree species in black gum swamps is desynchronized with that of black gum since these species have much shorter average life spans. These cycles occur on different time scales and in part reflect differential responses to disturbance. Based on our observations of several ancient black gum swamps that have been recently flooded and killed, beavers are probably a more serious threat to the longevity and maintenance of black gum at many sites than are hurricanes or other disturbance agents. However, further detailed age structure research is warranted to verify these observations and preliminary conclusions. The development of cross-dated tree chronologies, and more detailed stand development reconstructions of individual sites, will advance our understanding of the specific role of biotic and abiotic mechanisms in controlling stand development, including their variation within and between sites.

Once established, black gum may have several competitive advantages over associated tree species because of its longevity, shade tolerance, ability to reproduce vegetatively, and resistance to windthrow. Greater longevity is clearly an advantage because reproduction can occur less frequently and still result in the maintenance of the species at a site. Further, black gum's shade tolerance and longevity increases the chances of black gum becoming established in canopy openings created when individuals of other species die.

Black gum may rely heavily on vegetative reproduction for maintenance. Its clonal habit can produce other stems at least several meters from the main tree, if not much more, and confers an advantage to black gum for several reasons. First, extensive root systems that may develop in clonal black gum stands may provide more resistance to windthrow than for typical non-clonal species. Further, black gum has a tendency to lose upper branches during storms before entire stems blow over. The interconnections of plant ramets (stems from a single genetic individual) afforded by the clonal habit allow a genet to forage for resources and select habitat (Salzman 1985; de Kroon and Knops 1990; Evans and Cain 1995; Shumway 1995), and redistribute resources among ramets that experience stress, competition, or disturbance (Hartnett and Bazzaz 1985; Salzman and Parker 1985; Evans 1991; Hester *et al*. 1994; Shumway 1995; Pennings and Callaway 2000). Thus, black gum may benefit by being able to respond with considerable resources from new or advanced regeneration in micro-habitats that are temporarily inappropriate for the germination and establishment of other species from seed, as observed by Zebryk (1990) in a black gum swamp in Massachusetts. However, the reliance on sprouting from clones alone would limit black gum's ability to be distributed to other sites or even other portions of a single basin. The uneven or clumped distribution of black gum evident at many sites, and its absence from many basins with apparently suitable habitat (e.g., red maple basin swamps), is consistent with a pattern expected from a slow growing and shade tolerant species that relies primarily on sprouting from a clonal root system for maintenance. Stem density across all plots indicates that black gum is regenerating, but the extent to which black gum can and does regenerate from seed in the northern portion of its range is uncertain. We never directly observed flowers or fruits produced from a tree during the course of this study, although deliberate searches were not conducted.

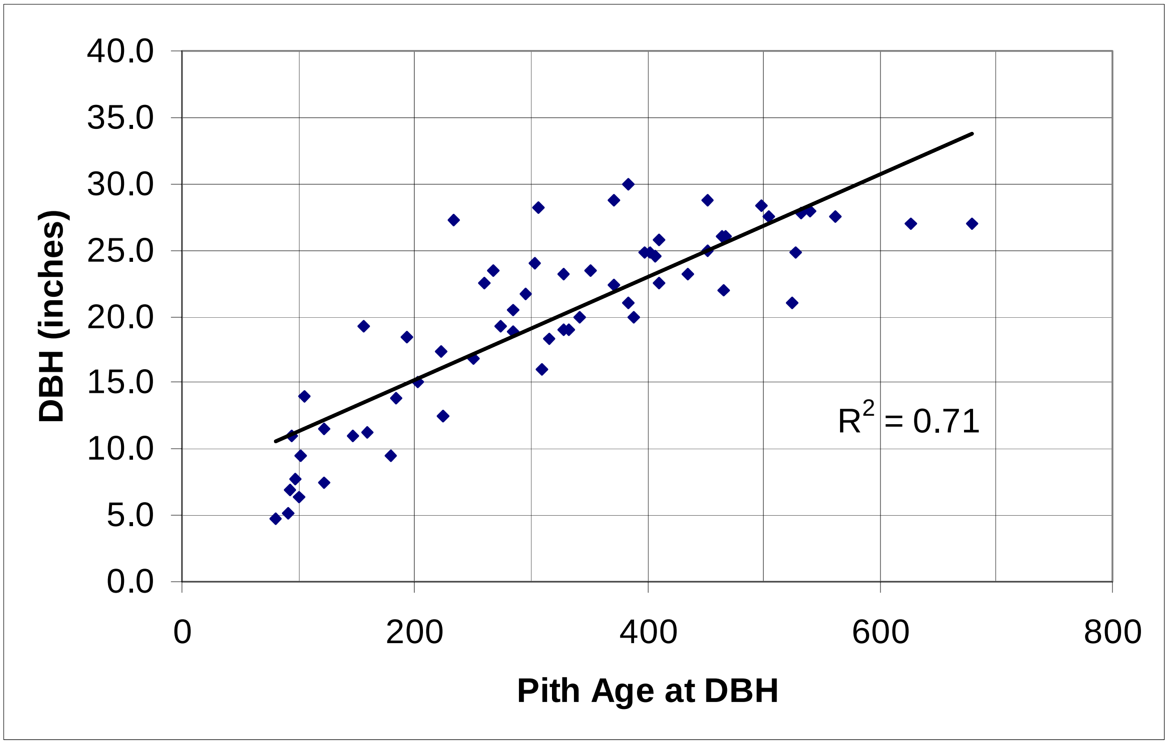


Figure 19. Linear regression between diameter at breast height (DBH) and pith age at DBH based on cores from 62 trees.

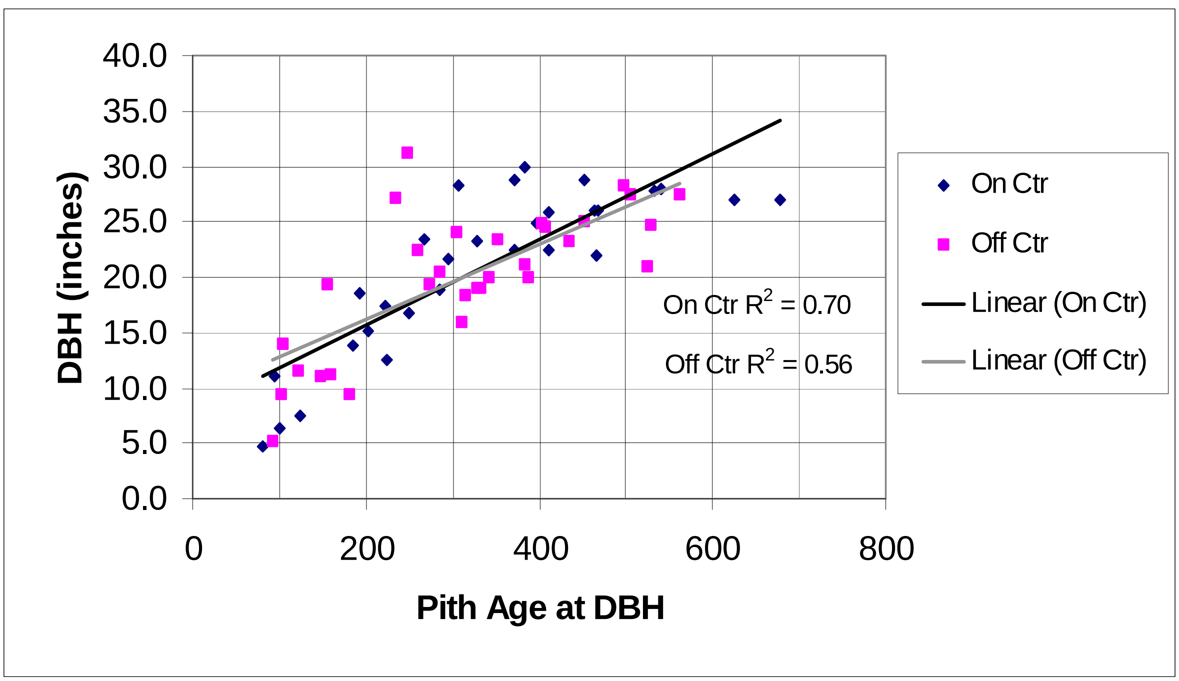


Figure 20. Relationship of DBH to pith age at DBH for black gum in NH basin swamps, based on 62 tree cores from 21 sites. Separate regressions are plotted for cores with tree ring counts within 5 years of center ("On Ctr" – n = 29) and for those within 5-15 years of center ("Off Ctr" – n = 33).

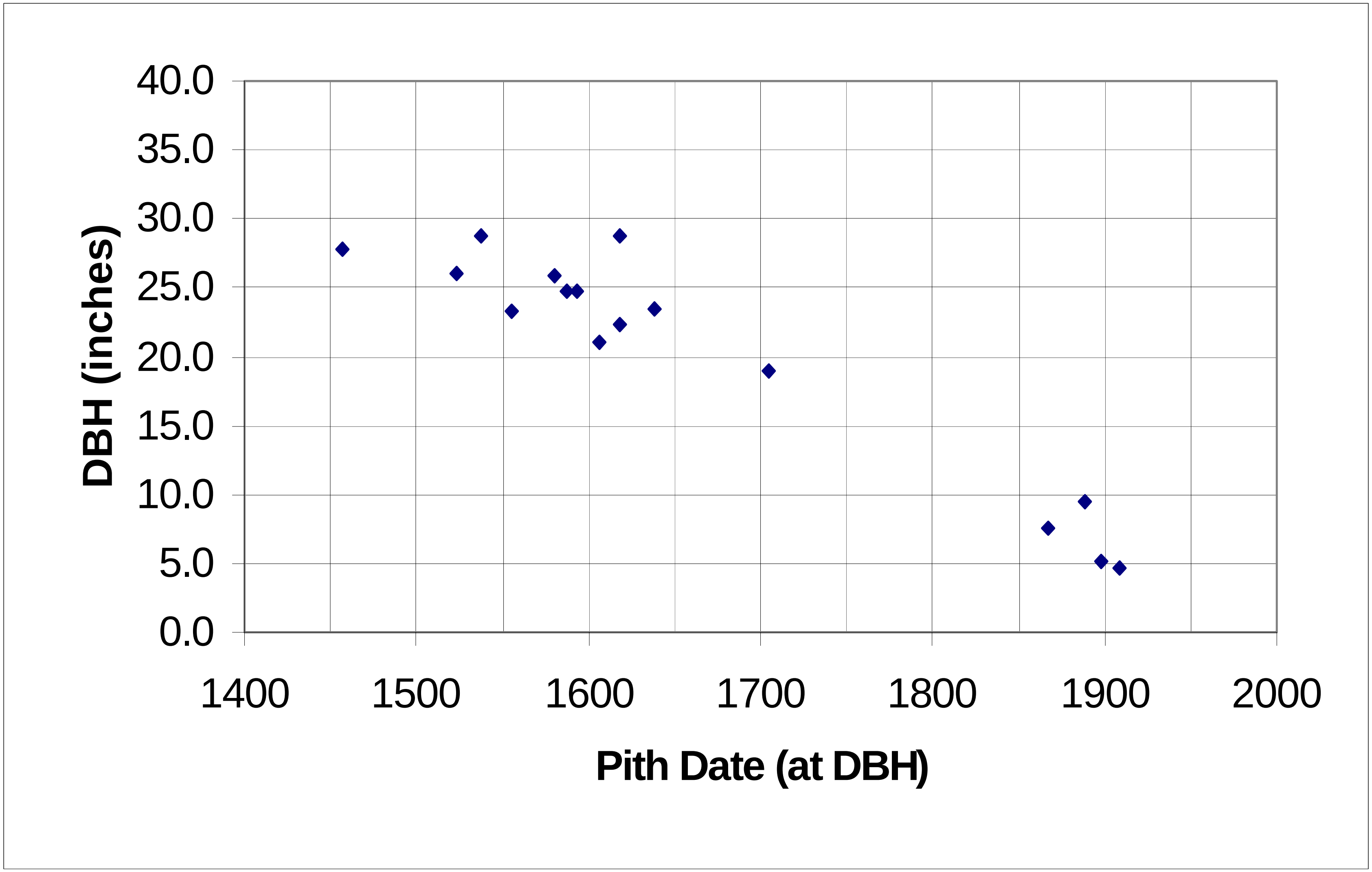
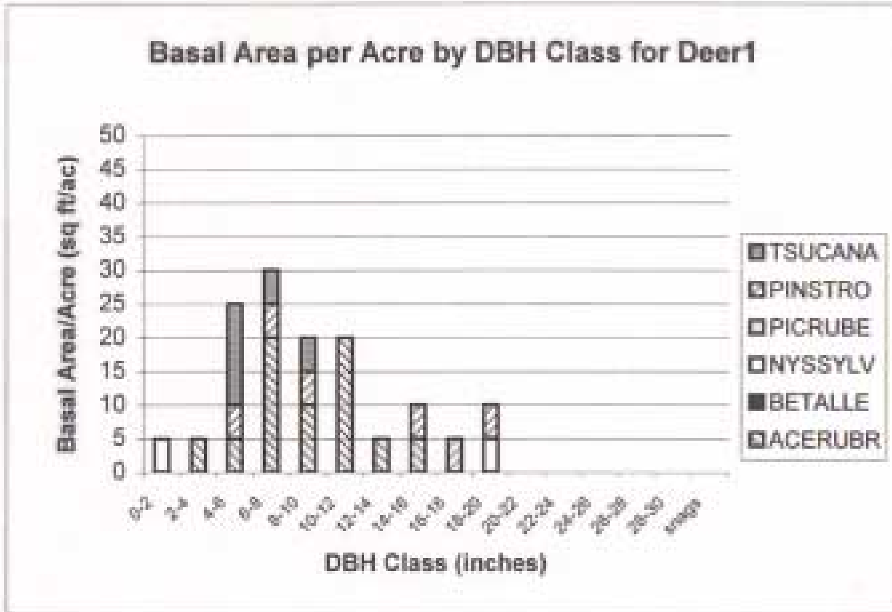
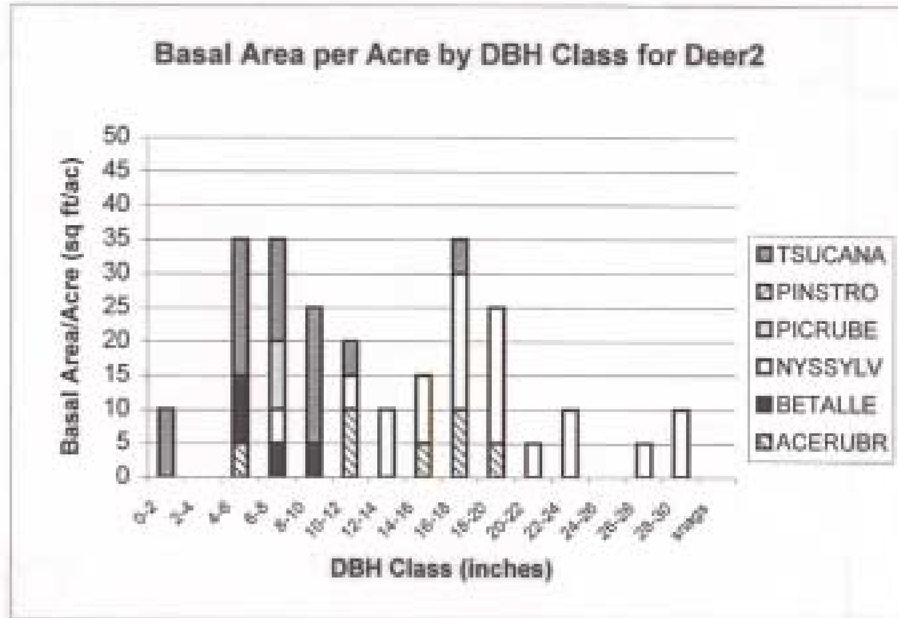


Figure 21. Stand development of Black gum (Nyssa sylvatica) at Deerfield Black Gum Swamp in Deerfield, NH. Coring was concentrated in the larger site classes (19-29 in. DBH). Pith dates represent estimated date the tree attained breast height, which post-dates germination by 5-25 years, depending on growing conditions.





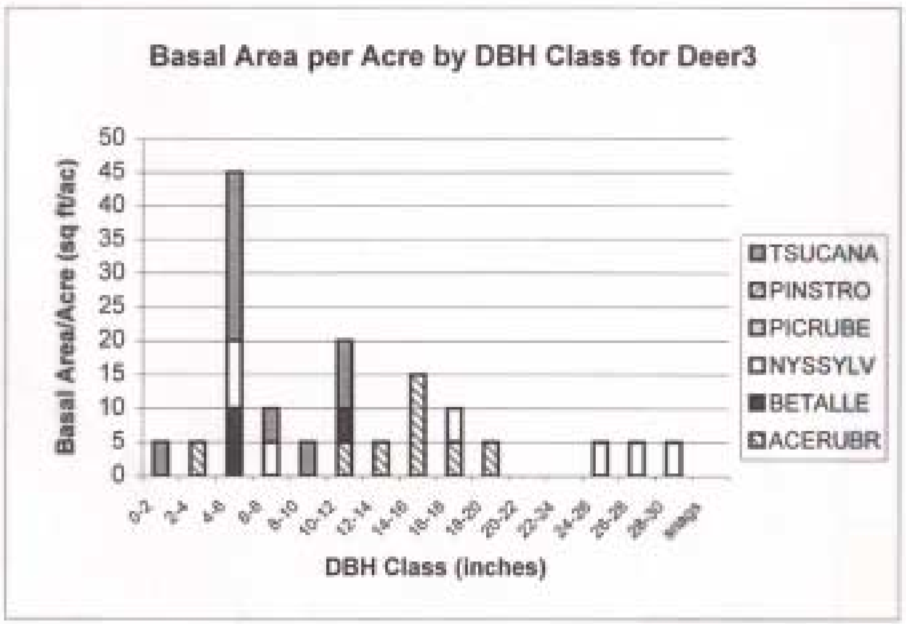


Figure 22. Basal area distributions of all tree species that achieved breast height at the Deerfield Black Gum Swamp. Deer1 is characteristic of a small, ca. one-acre area dominated by red maple. Deer2 and Deer3 are more characteristic of the remainder of the 20-acre basin. Size classes are present in these plots, although tree coring emphasized the larger size classes.

The relatively good age-diameter relationship for black gum may be attributable, in part, to the uniformly poor growing conditions found in black gum swamps. Sustained rapid growth of black gum may be precluded in New Hampshire swamp environments by low nutrient supplies, stressful hydrologic conditions, and proximity to the species' northern climatic limit. Clonal habit, longevity, and other life history strategies might confer an advantage to black gum in such environments if growth of species is more limited by environmental conditions than by inter-specific competition. Presumably, inter-specific competition in upland habitats is too great for black gum to succeed in these habitats near its northern climatic range limit. Preliminary results of a tree-ring chronology constructed from a small number of black gum cores at a New Hampshire black gum swamp (Berg *et al*. 1996) suggest that the growth of black gum may be correlated to climate variables such as temperature.

CONSERVATION OF BLACK GUM SWAMPS

RANKING CRITERIA

OCCURRENCE SPECIFICATIONS

The specifications outlined below are used to delineate and differentiate occurrences of the black gum–red maple basin swamp community, including those with a lakeshore component. They define what constitutes a valid occurrence (i.e., the minimum size, quality, or persistence required) and what distances or factors separate one occurrence from another.

The canopy of a black gum–red maple basin swamp or lakeshore is typically a mixture of *Acer rubrum* (red maple) and *Nyssa sylvatica* (black gum) with lesser amounts of *Tsuga canadensis* (hemlock), *Betula alleghaniensis* (yellow birch), *Picea rubens* (red spruce), *Pinus strobus* (white pine), and few other species. Total canopy cover ranges from 10% to over 75%. The shrub and herb layer may range from well to poorly developed. For lakeshore settings, a minimum single-width tree shoreline distance of 250 ft. [75 m] with black gum cover at least 3% of the absolute canopy cover and 10% of the total canopy cover is required to constitute an occurrence. Other minimum conditions for lakeshore occurrences are similar to those described below for black gum–red maple basin swamps.

While the total population size of black gum in a wetland contributes significantly to the community rank, it is also important that black gum be sufficiently concentrated to be prominent in the canopy in some part of the swamp. Meeting minimum dominance is one indication that conditions are appropriate for black gum to succeed under competition with other species and that the habitat is not marginal throughout the wetland.

In addition to black gum–red maple basin swamp, the basin in which this community occurs may also contain inclusions of aquatic bed, deep emergent marsh, shallow emergent marsh, shrub swamp, and red maple swamp.

The minimum conditions for a black gum–red maple basin swamp are the following:

1. total tree canopy cover of at least 10%;

2. at least a portion of a basin swamp (a minimum of 0.25+ ac. [0.1+ ha]) with the following conditions:
   a. absolute canopy cover of black gum at least 3%; and
   b. black gum contributes at least 10% of the total canopy cover; or
3. 10+ canopy black gum for a minimum sized (0.25 ac. [0.1 ha]) basin; or
4. 15+ canopy black gum in basins up to 1 ac. (0.4 ha); or
5. 20+ canopy black gum in basins 1-3 ac. (0.4-1.2 ha); or
6. 25+ canopy black gum in basins 3-9 ac. (1.2-3.6 ha); or
7. 30+ canopy black gum in basins >9 ac. (>3.6 ha); or
8. lower cover and/or fewer black gum/basin area if two or more basins occur in association with one another and collectively meet criteria above;
9. any recent logging should approximate natural disturbance (single tree replacement) and be light enough so that canopy cover is not meaningfully altered and soils and understory are not significantly impacted.

To ensure long-term viability of a black gum–red maple basin swamp, larger basin swamps may require fewer black gum per unit area (although with more total black gum trees) than would smaller basin swamps. This is based on the assumption that, all else being equal, long-term viability of black gum increases in larger basin swamps as a result of a corresponding increase in microhabitat suitable to support black gum. The minimum size recommended for a viable black gum–red maple basin swamp is 0.25 ac. (0.1 ha). Basin swamps below 0.25 ac. (0.1 ha) may not meet the minimum conditions required for a black gum–red maple basin swamp to ensure the long-term viability of the natural community.

Occurrences of black gum–red maple basin swamp are separated by either:

1. a substantial barrier between patches (e.g., a four-lane highway, urban development, open body of water); or
2. an area of cultural vegetation (including ruderal vegetation, such as old-fields) greater than 0.3 mi. (0.5 km); or
3. a different intervening natural or semi-natural community greater than 0.6 mi. (1 km); or
4. a major landform break or change in ecological land unit between patches (at the Land Type Association level of Keys *et al*. (1995)).

The separation distance for intervening cultural vegetation and natural and semi-natural communities is based on the suggested minimum value, since little is known about limitations on seed dispersal by black gum or shrub and herb species that occur in black gum–red maple basin swamps.

Quality Ranks

The "Quality Ranks" presented below give a more detailed picture of the significance and conservation value of individual black gum–red maple basin swamps based on the *condition*, *size*, and *landscape context* of each occurrence. These terms collectively refer to the integrity of natural processes or the degree of human disturbances that may sustain or threaten long-term survival.

CONDITION

Condition is a combined measure of development/maturity, degree of integrity of ecological processes, species composition, biological and physical structure, and abiotic physical factors within an occurrence. For example, old growth black gum–red maple basin swamps with little anthropogenic disturbance and intact biotic and abiotic factors, structures, and processes would warrant an "A" rank for condition regardless of size.

"A"-rated condition:

1. overstory structure intact (i.e., old growth has not been cut), with an appropriate size/age structure:
    a. greater than 150 total black gum trees at the site distributed by broad DBH classes as follows:

       >20 in. DBH class (ca. >300 year age class): more than 10 stems at the site and at least 5% of total number of stems (i.e., 1 in 20 trees are >20 in.);

       at least 5 of these should exceed 24 in. DBH or 400 years of age;

       12-20 in. DBH class (ca. 100-300 year age class): more than 30 stems and >20% of total number of stems (minimum of 10% acceptable if the >20 in. and 12-20 in. DBH classes together total >20%);

       2-12 in. DBH class (< 100 year age class): more than 50 stems total and between 25-75% of total number of stems;

       Note: The smaller two size classes (12-20 in. and 2-12 in.) ideally would not exhibit a narrow range of diameters within their ranges. A narrow range of diameters (e.g., most trees between 11 and 13 in.) might indicate that reproduction corresponds only to a single disturbance event.
    b. average age of associated canopy species may vary depending on hydrologic regime, especially red maple, a species with a broad hydrologic amplitude; generally, evidence of an "older tree phase" in basin swamps may require average ages >100 years for red maple and white pine and >150 years for red spruce, hemlock, and yellow birch; however, a "younger tree phase" for black gum canopy associates may not reflect evidence of logging but rather a greater susceptibility to disturbance or a response to other natural cycles and should be carefully considered;
    c. moderate to high diversity of snags and blowdowns in various stages of decomposition;

   d. structure is all-aged with multi-layered canopies;
   e. no evidence of logging
2. no significant flooding within the past year caused by beaver or human dams or other obstructions to outlet drainage (if present);
3. understory vegetation composed of native species.

"B"-rated condition:

1. typically a mature to older forest, younger than old growth, but with intact canopy;
   a. between 50-150 black gum trees at the site distributed by broad DBH classes as follows:

      >20 in. DBH class (ca. >300 year age class): more than 5 stems at the site and at least 5% of total number of stems (i.e., 1 in 20 trees are >20 in.);

      12-20 in. DBH class (ca. 100-300 year age class): more than 20 stems and >20% of total number of stems (minimum of 10% acceptable if the >20 in. and 12-20 in. DBH classes together total >20%);

      2-12 in. DBH class (< 100 year age class): more than 40 stems total and between 25-75% of total number of stems; or
   b. >150 black gum but not in proportions above; all classes are present in some quantity, but only 2 achieve minimum (for instance, there are less than 5 trees >20 in. or >300 years);
   c. evidence of mature to older black gum canopy associates; may require in basin swamps average ages >75 years for red maple and white pine and >100-125 years for red spruce, hemlock, and yellow birch; however, a "younger tree phase" for black gum canopy associates may not reflect evidence of logging but rather a greater susceptibility to disturbance or a response to other natural cycles and should be carefully considered;
   d. moderate diversity of snags and blowdowns in various stages of decomposition;
   e. structure contains moderately diverse layered canopies;
   f. if logging occurred, it was done long ago (>100 years ago) or if recent cutting has occurred, it is a very light selective cut approximating natural disturbance (single tree replacement) with little or no black gum removed; logging also should be light enough so that soils and understory vegetation are not significantly impacted;
2. if flooding has occurred within the past year from beaver or human dams or other obstructions to outlet drainage (if present), the hydrologic change is minimal or restricted to a small portion of the basin;
3. understory vegetation composed primarily of native species; non-natives (if present) are not sufficiently abundant to threaten natives.

"C"-rated condition:

1. typically a younger to nearly mature forest;
   a. 20-50 black gum in proportions above or with at least 2 of the size class conditions met (or all trees in one of two larger size classes); or

b. 50-150 black gum but only one size class present;

c. evidence of younger to nearly mature black gum canopy associates; may require in basin swamps average ages >50 years for red maple and white pine and >75 years for red spruce, hemlock, and yellow birch; however, a "younger tree phase" for black gum canopy associates may not reflect evidence of logging but rather a greater susceptibility to disturbance or a response to other natural cycles and should be carefully considered;

d. a low to moderate diversity of snags and blowdowns in various stages of decomposition may be present;

e. structure contains low to moderately diverse layered canopies;

f. any recent logging should approximate natural disturbance (single tree replacement) and be light enough so that canopy cover is not meaningfully altered and soils and understory are not significantly impacted;

2. flooding over two or more years caused by beaver or human dams or other obstructions to an outlet drainage (if present) may be more widespread and impact a significant portion of the basin; many of the canopy trees may be beyond recovery from anoxia or otherwise show signs of hydrologic stress;
3. non-natives understory vegetation (if present) may be sufficiently abundant to threaten some of the native plants.

"D"-rated condition:

1. black gum trees at the site distributed by broad DBH classes as follows:
   a. less than 20 black gum in any size class proportion; or
   b. 20-50 black gum with only small size class present (<12 in. DBH class); or
2. heavily cut swamp with significantly impacted canopy structure, soils, and understory, or significantly impacted by beaver or human related flooding resulting in the loss of nearly all of the tree canopy species;
3. non-natives understory vegetation (if present) may be sufficiently abundant to threaten many of the native plants;

Justification for "A"-rated condition: Based loosely on a standard of average black gum density across all plots (plot size ca. 0.1 ac. [0.04 ha]; n=30) extrapolated to trees/acre for a one acre area in each of three broad size classes (2-12 in., 12-20 in., and >20 in.) and using the average proportion of stems in each of those size classes as a minimum for an "A"-rated condition. That is, an "A"-rated condition is one that has average proportions of trees in each size class AND a population size for the site produced by the average frequency occurring over a one acre area (i.e., 150 black gum trees for the site). The assumption is that the plots, on average or at least the majority of them, represent high quality, viable black gum populations and thus black gum–red maple basin swamps. The rationale is that black gum needs some representation in multiple size and age classes for long term maintenance. Multiple age classes indicate existence of successful reproduction over time, the lack of major disturbance, and the presence of old-growth trees that provide evidence for the absence of clear-cutting or selective cutting since settlement. Trees over 20 in. are likely to average >300 years of age, and those greater than 24 in. are likely to average over 400 years.

Justification for "C"/"D" threshold: Recovery of a black gum–red maple basin swamp below the "C"/"D" threshold to a "C"-rated condition likely would take at least 100 years.

SIZE

Occurrence size is a quantitative measure of area occupied by the black gum–red maple basin swamp. All else being equal, the larger the occurrence, the more viable it will be. Large size is correlated with increased heterogeneity of internal environmental conditions, integrity of ecological processes, species richness, size of constituent species populations, population viability, potential resistance to change, resilience against perturbations, and ability to absorb disturbances. Size is used in a relative sense with respect to the range of sizes exhibited by black gum–red maple basin swamps.

"A"-rated size: Very large (>9 ac. [>3.6 ha].

"B"-rated size: Large (3-9 ac. [1.2-3.6 ha]).

"C"-rated size: Moderate (1-3 ac. [0.4-1.2 ha]).

"D"-rated size: Small (0.25-1 ac. [0.1-0.4 ha]).

Justification for "A"-rated size: Basins this size likely contain sufficient internal variability to ensure long-term viability. For a swamp complex consisting of two or more genetically connected basins that are hydrologically separated, total area may be somewhat smaller.

Justification for "C"/"D" threshold: Basins lack variability.

LANDSCAPE CONTEXT

Landscape context is a combined measure of (a) the quality of landscape structure, (b) the extent (including genetic connectivity), and (c) the condition of the surrounding landscape that influences the occurrence's condition and viability. Potential factors to be considered include: (a) the degree of landscape fragmentation; (b) the relationship of a black gum–red maple basin swamp to contiguous wetland or upland natural communities; (c) the influence of the surrounding landscape on susceptibility to disturbance; (d) the relative position in a watershed; (e) susceptibility of the occurrence to pollutants and hydrologic change; and (f) the functional relationship of the black gum–red maple basin swamp to surrounding natural landscape features and larger-scale biotic and abiotic factors.

In general, landscape condition is weighted towards the immediate 100-1000 ft. (30-300 m) buffer area around the black gum–red maple basin swamp where direct impacts of land use may be most significant. The adjacent 1-2 mi.^{2} (1.6-3.2 km^2) area or relevant watershed area around the occurrence is considered to a lesser degree. In turn, the larger area around that receives the least consideration.

"A"-rated landscape context: Intact – Landscape with little alteration; occurrence is completely surrounded by other high quality natural communities.

"B"-rated landscape context: Managed – Occurrence surrounded by partially disturbed natural or semi-natural communities, some of it not high quality due to recent logging.

"C"-rated landscape context: Fragmented – Occurrence surrounded by a mixture of moderate levels of agricultural and/or suburban development and adjacent forest lots.

"D"-rated landscape context: Agricultural or Suburban – Surrounding landscape primarily intensive agricultural or suburban development, and occurrence is at best buffered on one side by natural communities.

Justification for "A"-rated criteria: These characteristics most fully support the occurrence's condition and long-term viability.

Justification for "C"/"D" threshold: "C"-rated landscapes still provide a buffer against some edge effects, protect against abnormal levels of nutrient inputs to an occurrence, and provide functional connectivity between the occurrence and other natural communities.

CONSERVATION PRIORITIES

Presented below in Table 3 is a list of the highest quality black gum swamps in New Hampshire along with their natural community variant type(s), conservation status, and quality ranks. See Appendix 9 for a detailed description of these sites and information on their quality ranks. These sites were identified through landscape analysis, surveyed during the course of this study, and classified using ordination and other statistical methods. The high-quality sites listed in Table 3 contain examples of each of the three variants of the black gum–red maple basin swamp community. For each variant type, the highest quality privately owned black gum swamps should be primary targets for conservation. A limited number of additional, relatively high-quality sites exist in the state; information regarding these sites is available in the Heritage database.

Continued statewide surveys will advance our identification of conservation priorities in New Hampshire and increase our confidence that we have accurately selected *the* most important conservation priorities. Further, more information on the distribution and classification of black gum swamps outside of New Hampshire is required to better understand the global significance of the examples occurring in the state.

MANAGEMENT CONSIDERATIONS

Development is a significant threat to New Hampshire wetlands, including black gum swamps, particularly in the southern part of the state where these swamps are most likely to occur. A complicating difficulty in quantifying and qualifying potential impacts, however, is that too often the impacts of a specific activity on a wetland are considered in isolation of the cumulative impacts of development around the wetland. Development threats include fragmentation, habitat displacement and degradation, invasion of non-native species, alteration

Site	Variant Type	Conservation Status	Quality Rank
Deerfield	Mixture of all three variants	private	A
Blake's Hill Bog	Boggy forest/woodland and Hemlock forest/woodland	private	A
Big Island/Fundy Cove	Boggy woodland/tall shrub thicket	state owned	A/A-
Warner	Boggy forest/woodland	private	A-
South Deerfield	Hemlock forest/woodland	private	A-/B+

Table 3. List of the highest quality black gum swamps in New Hampshire.

of flood regimes, and impacts to water quantity and quality (including pollution, eutrophication, and reduction through withdrawal). Logging of forested black gum swamps may impact hydrologic patterns and alter habitat for forest-restricted species. Logging of adjacent uplands may influence hydrologic patterns, nutrient cycles, habitat integrity and fragmentation, and sedimentation.

Because black gum swamps are naturally acidic and low in nutrients, they are particularly susceptible to alteration by elevated nutrient inputs associated with development. The related management implication is to increase the size of buffer areas and limit or control certain activities near these wetland types. Buffers reduce the impact of disturbances outside the system and ensure that other characteristics and processes within the community remain intact. Buffers help protect natural communities from the deleterious effects of increased nutrients, reduced water quality, altered water quantity, invasion by exotic species, windthrow, loss of secondary plant or animal habitat, and future deleterious changes in surrounding land use that may increase threats over the long term. Deciding on an adequate buffer width is complicated, and depends on what impacts are being buffered against, the time frame for protection, and the level of impact or risk of impact that is acceptable. Nutrient-poor ecosystems, such as black gum swamps, may require larger setbacks than other systems because of their high susceptibility to changes in nutrient concentrations. Direct impacts are typically most serious within 300 ft. (90 m) of wetland areas.

As previously discussed, black gum swamps typically occur in topographically defined basins with stagnant or poor drainage and little seepage or alluvial influence. Given these hydrologic limitations, alterations to the hydrology of black gum swamps may significantly alter the species composition and certain functions of the community. The combined impact of humans and an expanding beaver population on wetlands in recent decades has modified the abundance of early-successional, deeper-water wetland types relative to later successional or shallower water types. Beavers have also dammed wetlands historically not occupied by beavers, including several examples of 400 to 600 year old black gum swamps that were flooded and killed in the early 1990's. Selective control of beaver and human impoundments may be appropriate to preserve unique examples of black gum basin swamp communities in New Hampshire.

LITERATURE CITED

Andrus, R. E. 1980. Sphagnaceae (Peat Moss Family) of New York State. Bulletin No. 442. New York State Museum, Albany, NY.

Applequist, M. B. 1959. A study of soil and site factors affecting the growth and development of swamp blackgum and tupelogum stands in southeastern Georgia. Ph.D. dissertation. Duke University, Durham, NC.

Baldwin, H. I. 1936. An Occurrence of Black Gum (Nyssa sylvatica Marsh.) in New Hampshire. Unpublished paper read before the NH Academy of Science, May 29, 1936.

Baldwin, H. I. 1961. Succession in a black gum – red maple swamp: a twenty five year record. Fox Forest Notes 86. Division of Forests and Lands, Concord, NH.

Baldwin, H. I. 1978. Black gum swamp: A 40-year record. Caroline A. Fox Research and Demonstration Forest Bulletin No. 19. Division of Forests and Lands, Concord, NH.

Berg, E., J. L. Grable, P. J. Krusick, J. Speer, D. Sperduto, and R. Villalba. 1996. Old black gum (Nyssa sylvatica), the longest tree-ring chronology in New Hampshire, USA. *In:* Brown, P. M. and P. J. Krusick. 1996. The Seventh Annual North American Dendroecological Fieldweek, August 16 to 25, 1996, Bartlett Experimental Forest, New Hampshire: Final Report.

Burkhalter, R. E. 1990. Flavonoid and phylogenetic analyses of the genus Nyssa (Cornaceae) in North America. Ph.D. dissertation. University of Alabama, Tuscaloosa, AL.

Burkhalter, R. E. 1992. The genus Nyssa (Cornaceae) in North America: A revision. Sida 15(2):323-342.

Chase, V. P., L. S. Deming, and F. Latawiec. 1995. Buffers for Wetlands and Surface Waters: A Guidebook for New Hampshire Municipalities. Audubon Society of New Hampshire, Concord, NH.

Cleavitt, N. L., R. E. Andrus, D. D. Sperduto, B. Nichols, and W. R. Town. *In press*. Checklist of *Sphagnum* in New Hampshire.

de Kroon, H. and J. Knops. 1990. Habitat exploration through morphological plasticity in two chalk grassland perennials. Oikos 59:39-49.

Dunwiddie. P. W. 1991. Forest history and composition of Halfway pond island, Plymouth county, Massachusetts. Rhodora 93(876):347-360.

Eastman, L. M. 1977. Tupelo, Nyssa sylvatica Marsh., in Maine and its relevance to the Maine Critical Areas Program. Planning Report No. 39. Maine State Planning Office, Augusta, ME.

Elias, T. S. 1980. The Complete Trees of North America: Field Guide and Natural History. Van Nostrand Reinhold Co., New York.

Evans, J. P. 1991. The effect of resource integration on fitness related traits in a clonal dune perennial, Hydrocotyle bonariensis. Oecologia 86:268-275.

Evans, J. P. and M. L. Cain. 1995. A spatially explicit test of foraging behavior in a clonal plant. Ecology 76:1147-1155.

Fernald, M. L. 1950. Gray's Manual of Botany, 8th ed. Dioscorides Press, Portland, OR.

Fosberg, R. R. and T. Blunt. 1970. Vernon Black Gum Swamp. Rhodora 72:280-282.

George, G. G. 1997. Vascular Plants of New Hampshire. NH Natural Heritage Inventory, Department of Resources and Economic Development, Concord, NH.

Gleason, H. A. and A. Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. New York Botanical Garden, New York.

Goldthwait, J. W. 1950. Surficial Geology Map. New Hampshire State Planning and Development Commission, Concord, NH.

Hartnett, D. C. and F. A. Bazzaz. 1985. The integration of neighbourhood effects by clonal genets in Solidago canadensis. Journal of Ecology 73:415-427.

Hersey, J. 1774. Plan of Ossipee Survey Map. *In:* Batchellor, A. S., ed.. 1896. Township Grants of Lands in New Hampshire included in the Masonian Patent Issued Subsequent to 1746 by the Masonian Proprietary. vol. 28. Edward N. Pearson, Concord, NH.

Hester, M. W., K. L. McKee, D. M. Burdick, M. S. Koch, K. M. Flynn, s. Patterson, and I. A. Mendelssohn. 1994. Clonal integration in Spartina patens across a nitrogen and salinity gradient. Canadian Journal of Botany 72:767-770.

Hill, M. O. 1979a. DECORANA – A FORTRAN program for detrended correspondence analysis and reciprocal averaging. Cornell University, Ithaca, NY.

Hill, M. O. 1979b. TWINSPAN – A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Cornell University, Ithaca, NY.

Keeley, J. E. 1977. The role of environmental heterogeneity in population differentiation along a flood frequency gradient. Ph.D. dissertation. University of Georgia, Athens, GA.

Keeley, J. E. 1979. Population differentiation along a flood frequency gradient: Physiological adaptations to flooding in Nyssa sylvatica. Ecological Monograms 49:89-108.

Keys, J. E. Jr., C. A. Carpenter, S. L. Hooks, F. G. Koenig, W. H. McNab, W. R. Russell, and M. L. Smith. 1995. Ecological units of the eastern United States: first approximation. U. S. Department of Agriculture, Forest Service.

Lyons, C. J. 1971. New Hampshire Natural Areas. New Hampshire Office of State Planning, Concord, NH.

Lyons, J. B., W. A. Bothner, R. H. Moench, and J. B. Thompson. 1997. Bedrock Geologic Map of New Hampshire. U.S. Geological Survey in cooperation with the U.S. Department of Energy and the State of New Hampshire.

McCune, B. and M. J. Mefford. 1997. PC-ORD. Multivariate Analysis of Ecological Data, Version 3.20. MJM Software Design, Gleneden Beach, OR.

McGee, C. E. 1990. Nyssa sylvatica Marsh. var. sylvatica. *In:* Burns, R. M. and B. H. Honkala, tech. coords. 1990. Sylvics of North America: 1. Conifers; 2. Hardwoods. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, DC.

New Hampshire Ecological Reserve System Project. 1998a. An Assessment of the Biodiversity of New Hampshire with Recommendations for Conservation Action. Concord, NH.

New Hampshire Ecological Reserve System Project. 1998b. Protecting New Hampshire's Living Legacy: A Blueprint for Biodiversity Conservation in the Granite State. Concord, NH.

Northern Forests Lands Council. 1994. Finding Common Ground: The Recommendations of the Northern Forests Lands Council. Concord, NH.

Orwig, D. A. and Abrams, M. D. 1994. Contrasting radial growth and canopy recruitment patterns in Liriodendron tulipifera and Nyssa sylvatica: gap-obligate versus gap-facultative tree species. Canadian journal of Forest Research 24:2141-2149.

Otis, C. H. 1931. Michigan Trees: A Handbook of the Native and Most Important Introduced Species. University of Michigan Regents, Ann Arbor, MI.

Peattie, D. C. A Natural History of Trees of Eastern and Central North America. Houghton Mifflin Co., Boston.

Pennings, S. C. and R. M. Callaway. 2000. The advantages of clonal integration under different ecological conditions: A community-wide test. Ecology 81(3):709-716.

Putnam, J. A. 1951. Management of bottom land hardwoods. U. S. Department of Agriculture, Forest Service Occasional Paper 116. Southern Forest Experiment Station, New Orleans, LA.

Salzman, A. G. and M. A. Parker. 1985. Neighbors ameliorate local salinity stress for a rhizomatous plant in a heterogeneous environment. Oecologia 65:273-277.

Seymour, F. C. 1993. The Flora of New England. 2nd ed. Privately printed.

Shumway, S. W. 1995. Physiological integration among clonal ramets during invasion of disturbance patches in a New England salt marsh. Annals of Botany 76:225-233.

Sperduto, D. D. 1994. A Classification of the Natural Communities of New Hampshire. April 1994 ed. NH Natural Heritage Inventory, Department of Resources & Economic Development, Concord, NH.

Sperduto, D. D. 1997. A Preliminary Classification of Natural Communities in the New Hampshire Coastal Lowlands Ecoregion. NH Natural Heritage Inventory, Department of Resources & Economic Development, Concord, NH.

Ter Braak, C. J. F. 1988. CANOCO: A Fortran Program for Canonical Community Ordination. Microcomputer Power, Ithaca, NY.

Vogelmann, H. W. 1969. Vernon Black Gum Swamp. Natural Areas in Vermont, Report No. 2:7-8. Central Planning Office, Montpelier, VT.

Vogelmann, H. W. 1976. An unusual black gum swamp in Maine. Rhodora 78:326-327.

Wen, J. and T. F. Stuessy. 1993. The phylogeny and biogeography of Nyssa (Cornaceae). Systematic Botany 18(1):68-79.

Zebryk, T. 1990. Vegetation and site characteristics of a Nyssa-dominated wetland in central Massachusetts. DRAFT. Harvard Forest, Harvard University, Petersham, MA.

Appendix 1. Explanation of global and state rank codes.

Ranks describe rarity both throughout a species' range (globally, or "G" rank) and within New Hampshire (statewide, or "S" rank). The rarity of sub-species and varieties is indicated with a taxon ("T") rank. For example, a G5T1 rank shows that the species is globally secure (G5) but the sub-species is critically imperiled (T1).

Code	*Examples*		*Description*
1	G1	S1	Critically imperiled because extreme rarity (generally one to five occurrences) or some factor of its biology makes it particularly vulnerable to extinction.
2	G2	S2	Imperiled because rarity (generally six to 20 occurrences) or other factors demonstrably make it very vulnerable to extinction.
3	G3	S3	Either very rare and local throughout its range (generally 21 to 100 occurrences), or found locally (even abundantly at some of its locations) in a restricted range, or vulnerable to extinction because of other factors.
4	G4	S4	Widespread and apparently secure, although the species may be quite rare in parts of its range, especially at the periphery.
5	G5	S5	Demonstrably widespread and secure, although the species may be quite rare in parts of its range, particularly at the periphery.
U	GU	SU	Status uncertain, but possibly in peril. More information needed.
H	GH	SH	Known only from historical records, but may be rediscovered. A G5 SH species is widespread throughout its range (G5), but considered historical in New Hampshire (SH).
X	GX	SX	Believed to be extinct. May be rediscovered, but evidence indicates that this is less likely than for historical species. A G5 SX species is widespread throughout its range (G5), but extirpated from New Hampshire (SX).

Modifiers are used as follows.

Code	*Examples*		*Description*
Q	G5Q	GHQ	Questions or problems may exist with the species' or sub-species' taxonomy, so more information is needed.
?	G3?	3?	The rank is uncertain due to insufficient information at the state or global level, so more inventories are needed. When no rank has been proposed the global rank may be "G?" or "G5T?"

When ranks are somewhat uncertain or the species' status appears to fall between two ranks, the ranks may be combined. For example:

G4G5	The species may be globally secure (G5), but appears to be at some risk (G4).
G5T2T3	The species is globally secure (G5), but the sub-species is somewhat imperiled (T2T3).
G4?Q	The species appears to be relatively secure (G4), but more information is needed to confirm this (?). Further, there are questions or problems with the species' taxonomy (Q).

G3G4Q S1S2   The species is globally uncommon (G3G4), and there are questions about its taxonomy (Q). In New Hampshire, the species is very imperiled (S1S2).

Appendix 2. List of potential black gum swamps arranged by topographic quadrangle.

In general, the quadrangles are sorted from east to west beginning in the southeastern corner of New Hampshire. All medium to large basins, or concentrations of small basins with NWI designations of PFO1E, PFO1/4E, or PFO4/1E were marked on the quad maps. Of these basins, the ones with the highest potential for black gum swamps are those that occur high in the watershed, coincide with basins identified by Thematic Mapping, are designated PFO1/4E, and have muck and peat soils associated with soil types that are rocky, stony fine sandy loam complexes. Other sites are listed based on leads from conservation commissions and other knowledgeable organizations and individuals.

The wetlands identified below have not been surveyed by NH Heritage, and may or may not actually contain black gum trees.

Sites are indented under each quadrangle name according to the following format:

******	**Indicates sites with the highest potential for black gum swamp(s)**
*****	**Indicates sites with high potential for black gum swamp(s)**
+	Indicates leads from knowledgeable organizations and individuals
(#,#)	Indicates the approximate left-to-right and top-to-bottom position on the 7.5 minute quadrangle, respectively, if the quadrangle was broken into a 10 block by 10 block grid
C.00#	Indicates NH Heritage community occurrence # for sites in NH Heritage database

Quadrangle	Comments
Pepperell	
	+ phone lead, needs follow-up
Haverhill MA, NH	
	***(5,3) Possible swamp stand NW of Brandy Brow Hill**
	(1,1) Perched swampy areas, soils not promising
Salem Depot	
	***(2,5) West of Zion Hill Road, with Rhododendron viscosum**
	***(1,1) Brandy Rock Hill/Kilrea Road, 2 sites**
	***(1,4) Gordon's Hill, a couple of sites**
Windham	
	***(5,10) Rt. 111A site, Pelham, with Rhododendron viscosum**
	***(7,9) Pelham, with Rhododendron viscosum**
	***(5,2) Derry, just east of Route 93**
South Merrimack	
	***(2,3) Crickett Corner, Amherst, near road**
Sandown	
	****(7,2) Fremont A, large PFO1/4E/Mp site east of Fremont and Exeter River Reservoir**
	****(6,2) Fremont B**

Quadrangle	Comments
Derry	
	****(3,4) Several patches of good soil/NWI codes, running north from junction of Rt. 28 and Auburn/Londonderry line**
	***(1,4) Good soils and NWI in small valley on south edge of Rattlesnake Hill**
	***(5,5) Two wetland complexes with good NWI and soils, near junction of Old Couch and Auburn Roads**
	***(2,7) Small PFO4/1E patch west of Scobie Pond**
	***(6,1) Small site SOUTH of Spruce Swamp**
	(6,2) Small patches of PFO4/1E on various soils
	(7,6) Small wetland north of Beaver lake
	(5,3) Small patches on southeastern slope of Silver Hill
Manchester South	
	***(7,5 and 8,5) Two potential patches near Hillsborough/Rockingham County line**
	(7,9) Small patch surrounded by recent (1980s?) development
Pinardville	
	(6,2) Small patch on west slope of Walnut Hill
	(5,7) Small patch west of Jappa Hill Road
New Boston	
	***(4,7) Two basin wetlands south of Horton's Pond**
	***(7,7) Small perched basin NE of Prospect Hill summit**
	(2,6 to 2,8) Swath of small NWI polygons with good soils, west of Salisbury Road, no gum
	(1,3) Patch on map edge, north of Old Coach Road
	(8,6) Small perched basin north of Remington Rd, on south boundary of Satellite Tracking Annex
	+ SPNHF lead site
Greenfield	
	(10,10) Wetland east of south Lyndeborough
	+ Piscataquog Mt. site
Newmarket	
	+(3,9) Exeter red maple/conifer basin swamp
Dover West	
	***(5,7) Reservoir Hill, side of Rt. 4, north of Durham Reservoir, can see wetland from road**
	(1,1) Small patch upstream of drainage into Isinglass River
	(2,3) Diffuse cloud of patches with possible NWI/soil designations
	(2,8) Small patches west of Steven’s Hill
	(10,8) Roadside patches along Jenkins Road
Epping	
	***(1,4) Two patches on Kennard Hill, no response on permission, see (1,1)**
	(1,1) Two patches tucked in hills north of Flutter Street
	(2,1) Site surrounding North River
	(9,3) Small site west of Glenmere Village
	(5,5) Two wetlands west of Berry Road
	(10,5) Marshy area south of Bald Hill (?)
	(8,7) Flat area south of Camp Hedding.
	(2,9) Patches south of Brown Brook
	(3,10) Area northeast of Spruce Swamp
	(8,10) Small patch east of Deer Hill Road, in association with wetlands to south of Rt. 101
	(10,9) Small patch south of Fresh River

Quadrangle	Comments
Mt. Pawtuckaway	
	(1,4) Patch in basin west of Lamprey River
	(4,5) Flat wetland complex west of Governor's Lake
	(8,6) Rolling hill/basin complex west of Heath Road
	(2,7) Patch west of Rattlesnake Hill
	(9,10) Swath of patches in circular area east of Route 107
Candia	
	(2,3) Narrow patch surrounding wetland west of North Road
	(7,5) Wetland patch SE of Candia Four Corners; associated with two other patches, both just north of Boston and Maine railroad tracks
Manchester North	
	***(9,3) Hooksett A, large basin, high potential site north of Clay Pond, associated with smaller sites along Chester Road**
	(8,2) Wetland flowing north and west along state park boundary
	(7,5) Wetland along Whitehall Rd, just east of Campbell Hill
	(8,6) Several low potential sites west of Tower Hill Pond.
	(1,5 to 1,7) Swath of small wetland patches and mucky soils on map edge, south of Merrimack and Hillsborough county boundary
Goffstown	many small swaths of patchy PFO1E around low hills and basins throughout quad. Variable soils. Not all noted below.
	***(4,8) Wetland and satellite patches west of Paige Hill Road**
	***(6,7) Small wetland patch northwest of Tirrell Pond**
	***(8,3) Collection of small PFO1 patches and central muck soil patch east of powerline and south of South Bow Road**
	(5,4) Small patch along drainage south of Morse Road
	(10,6) Small wetland near Hillsborough/Merrimack Cty. boundary
Weare	many small swaths of patchy PFO1E around low hills and basins throughout quad. Variable soils. Not all noted below.
	(5,3) Barnard Hill??
	(4,3) Various patches on east side of Mt. William
	(8,3) Complex of possible sites surrounding the open water north of Gorham Pd.
	(8,5) Swath of small patches at Hillsborough/Merrimack Cty. corner
	(9,10) Basin south and east of Rt. 13
	+ Dunbarton, south off Everett Mansion Road
Deering	several additional medium sized potential sites
	***(6,2) Two patches north of Weare Reservoir, roadside swamp**
	***(9,5) Basin east of Peacock Brook**
	***(1,6 to 1,7) Patches north and south of Wilson Hill summit**
	***(2,10) Patch west of Campbell Hill**
	(10,4) Possible site south of Clinton Grove
	(9,6) Ferrin Pond
Hillsboro	
	***(1,2) Patch north of Bagley Pd.**
	***(9,4) Two patches east of West Deering**
	***(5,9) Medium size patch south of Antrim and southeast of Nahor Hill**
	(10,4) Conifer dominated patch east of Hedgehog Hill ridge
Barrington	
	(6,4) Northeast drainage into Swains (Union) Lake, east of Beauty Hill Road
	(7,5) Patchy distribution south of Hall Road, across from campground
	(9,6) Conifer dominated patch west of Rt. 125
	(2,2) Collection of patches south of Province Road

Quadrangle	Comments
Northwood	several small patches not noted that may be promising
	(9,10) Swath of small patches south and east of Duke Hill
Gossville	numerous potential sites not noted below
	*?(7,5) Basin around Dow Pond, just to north, and to south around Mud Pond
	(5,6) Just south of Swamp Road and west of Rockingham/Merrimack Cty border
	(5,8) Several medium size patches and satellites to west and north of Thurston Pond
Suncook	
	(5,4) Perched wetland north of Sixth Range Road with satellite patches to north and east
	(10,9) Riparian wetland along Catamount Brook near map edge
Hopkinton	
	***(7,7) Hopkinton, roadside swamp**
Henniker	
	(10,4) Wetland patch south of Rolf Pond
	(6,9) Wetland south of Craney Pond
	(3,5) Several small perched patches on east slope of Liberty Hill and east
Hillsboro Upper Village	
	(6,2) Perched valley south of Lake Massasecum
	(9,2) Perched valley southeast of Lake Massasecum, east of Rt. 114
Baxter Lake	many small patches throughout quad
	***(3,8) High concentration of small patches west of Berry's Corner**
	(1,2) Small perched valleys southwest of Hornetown, with satellite patches north and northwest of Nubble Pond
	(1,5 to 2,6) Small patches spread southeast of "W488T" pond
	(9,10) Map edge patches
	?(4,10) Long Pond
Parker Mt.	
	(8,9) Satellite patches NE of Bow Lake
Pittsfield	
	***(1,4) Medium patch north of Rings Corner**
	***(8,8) Patches in hilly flats east of Eaton Pond**
	(2,5) Two patches south of Rings Corner
Loudon	
	***(3,9) Hilly valleys south of Soucook River State Forest**
	***(1,10) Hill patches and satellites in map corner**
	(1,5) Large linear patch surrounding Hunting Swamp
	(1,6) Flat area along Pine Island Brook (floodplain?)
	(8,5) Small wetland south of Loudon Center
	(7,7) Two patches on either side of Bear Hill
Holderness	
	(9,3) Muck area on west side of Dog Cove
	(5,8) Patch east of Forest Pond
Squam Mountains	
	(8,10) Several small patches on Long Island

Appendix 3. List of all sites at which black gum trees were recorded.

USGS Quadrangle	Site Name	Town
EXETER	Fort Rock	Exeter
	The Cove	Kensington
	Rte. 107 Detention Basin	Seabrook
	Pow Wow River	South Hampton
TOWNSEND	Beaver Brook Black Gum	Hollis
HAVERHILL	N Plaistow Perched Basins	Plaistow
SALEM DEPOT	Windham/Salem Townline	Windham
NASHUA NORTH	Rocky Hill Pond	Litchfield
	Grassy Pond	Litchfield
MILFORD	Mason Rhododendron Swamp	Mason
GREENVILLE	New Ipswich	New Ipswich
KINGSTON	Gas Pipeline	Newton
SANDOWN	Chester 2	Chester
	Chester 3	Chester
	Island Pond Black Gum peninsula	Hampstead
MANCHESTER SOUTH	Lake Massabesic	Manchester
PINARDVILLE	Powder Hill	Bedford
NEW BOSTON	Lyndeboro Black Gum	Lyndeboro
	Green Tree Reservoir	New Boston
	Shaky Pond Outlet	New Boston
	Scobie Rd/136 Jct.	New Boston
HINSDALE	Pisgah State Park	Winchester
BRATTLEBORO EAST	Mt. Wantastiquet	Hinsdale
DUBLIN	Mud Pond	Dublin
	Eastview	Harrisville
KEENE	Horatio Colony Reserve	Keene
PORTSMOUTH	Paul Brook Watershed	Newington
	Bass Pond Road Site	Newington
	Hodgdon Brook Watershed	Portsmouth

Quadname	Site Name	Town
NEWMARKET	Deene Easement	Exeter
	Shackford Point	Newington
NEWMARKET	Sandy Point	Stratham
DOVER EAST	Bellamy River WMA & Access	Dover
	Clement Point	Dover
DOVER WEST	Pudding Hill	Dover
EPPING	Langdon Swamp	Epping
	Fred Doe	Newmarket
	North River	Nottingham
MT. PAWTUCKAWAY	Big Island	Nottingham
	Fundy Cove Black Gum	Nottingham
	South of Mt Pond	Nottingham
CANDIA	Kinnicum Pond	Candia
	Chester1 - Candia Rd	Chester
	S Deerfield Black Gum SW	Deerfield
	Candia Rd	Deerfield
MANCHESTER NORTH	Manchester Cedar Swamp	Manchester
GOFFSTOWN	Flintrock	Dunbarton
	Leg Ache Hill Road	Dunbarton
WEARE	Champ	Dunbarton
BARRINGTON	Ayers Pond	Barrington
	Old Canaan Road	Barrington
	Barrington Cedar Swamp	Barrington
	SW of Nippo Pond	Barrington
	Powerline Gum	Nottingham
	Davis Pond Basin	Nottingham
NORTHWOOD	Rte. 43 Swamp	Deerfield
	Pendleton	Deerfield
	Deerfield Black Gum	Deerfield
	E of Freeses Pond	Deerfield
	Blakes Hill Bog	Northwood
	Northwood Meadows State Park	Northwood
	Northwood/Barrington town	Northwood
	Coffeetown Rd	Northwood
	Site Y6	Northwood
	Site G11	Northwood
	Site G7	Northwood
	Stevens Hill	Nottingham
	Deerfield Black Gum	Nottingham
	Dawsons Swamp	Nottingham
	Mulligan Ponds	Nottingham
	Swamp E of Kenison Pond	Nottingham

Quadname	Site Name	Town
GOSSVILLE	Potavin Black Gum	Deerfield
	Babb Swamp	Deerfield
	Fort Mt	Epsom
	Site Y10	Northwood
	Pleasant Pond N	Northwood
	Site G10	Northwood
SUNCOOK	Chichester/Epsom Townline	Chichester
CONCORD	Garvin Falls	Concord
HOPKINTON	Hop-Ev South	Dunbarton
	Hop-Ev North	Hopkinton
HENNIKER	NW of Bear Pond	Warner
HILLSBORO UPPER VILLAGE	Fox State Forest	Hillsborough
	Warner Black Gum swamp	Warner
BAXTER LAKE	Barrington Black Gum Swamp	Barrington
	NNE of Meaderboro Corner	Rochester
PARKER MOUNTAIN	Strafford	Strafford
LOUDON	Coaster Rd	Loudon
BRADFORD	Wadleigh State Park	Sutton
WOLFEBORO	Rt.28 Black Gum	Alton
	Point O' Pines Road	Wolfeboro
CENTER HARBOR	Meredith Neck SE	Meredith
	Meredith Neck NW	Meredith
	Salmon Meadow Cove	Moultonborough
HOLDERNESS	Center Harbor Neck	Center Harbor
NEWFOUND LAKE	Newfound Lake	Hebron
OSSIPEE LAKE	Ossipee Pond	Ossipee
SQUAM MOUNTAINS	Fiver finger Point	Sandwich
	Hoag Island	Sandwich
	Rattlesnake Cove	Sandwich
	Metcalf Point	Sandwich
CONWAY	Conway / Eaton town line	Conway
BELLOWS FALLS	Bellows Falls	Walpole
SUNAPEE LAKE NORTH	Lake Sunapee	Sunapee

Appendix 4. Tree cores taken at black gum sites in New Hampshire.

Tree cores were taken from black gum, red maple, red spruce, hemlock, and yellow birch trees at selected sites between 1993 and 2000.

Column Codes

Site: Wetland or wetland complex where the tree core was collected.

Date: Day the core was extracted.

Town: Town where the site is located.

County: BELK = Belknap; CARR = Carroll; CHES = Cheshire; HILL = Hillsborough; MERR = Merrimack; ROCK = Rockingham.

Species: Tree species cored.

DBH: Diameter-at-breast height of tree cored.

BA: Basal area of tree cored.

Ring Cnt.: Total number of rings counted in the core.

Part. Cnt.: Total number of countable rings in cores that were partial or that had unreadable sections.

Site	Date	Town	County	Species	DBH	BA	Ring Cnt.	Part. Cnt.	Notes (cc = likely a conservative count)
Babb Swamp	3/25/1997	Deerfield	ROCK	*Nyssa sylvatica*					Partial core; extracted before reaching center; possible rotten center.
Beaver Brook Bgum	10/9/1997	Hollis	HILL	*Nyssa sylvatica*	21.7	369.8	295		cc; very difficult to read after 260 rings.
Beaver Brook Bgum	10/9/1997	Hollis	HILL	*Nyssa sylvatica*	19.6				
Beaver Brook Bgum	10/9/1997	Hollis	HILL	*Nyssa sylvatica*	19.3	292.5	274		cc
Big Island (Pawtuckaway)	5/15/1997	Nottingham	ROCK	*Nyssa sylvatica*					
Blakes Hill Bog	9/18/1998	Northwood	ROCK	*Nyssa sylvatica*	27.0	572.5	626		Tree #1. ca. 100m S of bog in ancient grove.
Blakes Hill Bog	5/12/1999	Northwood	ROCK	*Nyssa sylvatica*	21.0	346.4	525		Tree #2 or #3. Next to Tree #1. Fast growing first hundred years.
Blakes Hill Bog	5/12/1999	Northwood	ROCK	*Nyssa sylvatica*	25.0	490.9	452		Tree #4. Due north of Tree #1. Uniform ring width throughout.
Blakes Hill Bog	5/12/1999	Northwood	ROCK	*Nyssa sylvatica*	25.0			120	Tree #4. Due north of Tree#1. Missing part (most) of core.
Blakes Hill Bog	5/12/1999	Northwood	ROCK	*Nyssa sylvatica*	27.0	572.5		650	Tree #5. 12m N of Tree #1, 5m E of Tree #4. Uncertain count.
Blakes Hill Bog	3/25/2000	Northwood	ROCK	*Nyssa sylvatica*	27.0		679		Tree #5. Cored directly to center; readable throughout.
Chester 1-Candia Rd	11/2/1998	Chester	ROCK	*Nyssa sylvatica*	22.0	380.1	465		
Chester 1-Candia Rd	11/6/1998	Chester	ROCK	*Nyssa sylvatica*	24.8	481.1	528		Slow growing second hundred years, "blanched" outer rings
Chester 1-Candia Rd	11/6/1998	Chester	ROCK	*Nyssa sylvatica*	28.3	626.8	306		Extremely wide rings for a black gum.
Chester 1-Candia Rd	11/6/1998	Chester	ROCK	*Nyssa sylvatica*	23.3	424.5	328		Easily readable rings throughout; cored directly to center.
Chester 3-Green Rd	11/2/1998	Chester	ROCK	*Nyssa sylvatica*	18.5	268.8	193		
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Acer rubrum*	6.2		100		Easily countable wide rings.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Acer rubrum*	17			100	Punky core near outer edge, perhaps ca. 30 more years.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Acer rubrum*	9.5		76		
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Acer rubrum*	13.4		119		
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Acer rubrum*	16.5				Difficult to count.
Deerfield Bgum Swamp	10/30/1996	Deerfield	ROCK	*Nyssa sylvatica*	30.0	706.8	384		DBH is an estimate from memory; "Quincy" largest tree.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	21.1	348.4		380	Tree leaning N, on edge of swamp; similar count to 1b.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	21.1	348.4	384		Tree leaning N, on edge of swamp; similar count to 1a.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	21.3	355.0		319	Apparently punked out in middle; unable to count total age.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	20.7	335.5		290	Tree leaning E, core taken from W side; many "washed out" rings.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	18.9	280.5	285		Very difficult to read the outer 50 years or so.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	18.9	280.5		280	Very difficult to read the outer 50 years or so.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	26.0	530.3	467		Not girdled; blue/black coloration near center of core.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	24.8	483.2		400	65% girdled (by beavers).
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	24.8	483.2	403		
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	23.2	423.8	435		Right side of core reversed in mount, but center clearly visible.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	22.4	394.1	372		Not girdled; outer rings crumbly in core mount.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	24.8	483.2	397		50% girdled; 392+ca.5 to center?; some ambiguity in sections.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	27.8	605.0	533		50% girdled; some very tight sections, but mostly readable.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	25.8	522.3	410		30% girdled; part of core reversed in mount, but quite readable.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	23.6	438.2		170	Not girdled; core unreadable past first 150 years of growth.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	9.4	70.1	102		Girdled, difficult to pick out faint rings.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	5.2	21.2	92		Girdled; cc, extremely bleached, thin, soft outer rings.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	23.4	431.0	352		Difficult to count non-distinct pale rings.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	28.3	631.1			Uncountable, partial core.

Site	Date	Town	County	Species	DBH	BA	Ring Cnt.	Part. Cnt.	Notes (cc = likely a conservative count)
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	28.3	631.1			Uncountable, extremely crumbly punky core.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	28.7	648.7	372		Fast growing first hundred years (thick inner rings).
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	28.7	648.7	452		Not girdled; all surrounding RM and hemlock are dead.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	13.0	132.6			Unreadable.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	13.0	132.6			Unreadable.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	19.7	304.3			
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	7.5	43.9	123		Clearly readable rings; core directly to center.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	7.5	43.9			Difficult outer rings.
Deerfield Bgum Swamp	3/28/1993	Deerfield	ROCK	*Nyssa sylvatica*	4.7	17.5	81		Black smudges on core.
Deerfield Bgum Swamp	8/14/1996	Deerfield	ROCK	*Nyssa sylvatica*	27.5		562		
Five Finger Point	9/4/1997	Sandwich	CARR	*Nyssa sylvatica*	16.0	201.1		220	Last few rings blend into soft bark; cored right to center.
Five Finger Point	9/4/1997	Sandwich	CARR	*Nyssa sylvatica*	23.4	430.0	267		Just W of swampy part of OP 2; no sections of notably thin rings.
Five Finger Point	9/4/1997	Sandwich	CARR	*Nyssa sylvatica*	20.0	314.2	342		cc
Five Finger Point	9/4/1997	Sandwich	CARR	*Nyssa sylvatica*			82		No core data; est. 7" DBH; rings easily readable.
Flint Rock	8/14/1997	Dunbarton	MERR	*Nyssa sylvatica*	31.2	764.5	247		
Fox State Forest	10/30/1998	Hillsborough	HILL	*Nyssa sylvatica*	11.5	103.9	122		
Fox State Forest	10/30/1998	Hillsborough	HILL	*Nyssa sylvatica*	24.0	452.4	304		
Fox State Forest	10/30/1998	Hillsborough	HILL	*Nyssa sylvatica*	22.5	397.6	410		Very fast growing first hundred years.
Fundy Cove Bgum	10/30/1997	Nottingham	ROCK	*Nyssa sylvatica*	19.8			256	Missing punky center; core surface heavily scratched; 306 years?
Fundy Cove Bgum	10/30/1997	Nottingham	ROCK	*Nyssa sylvatica*	12.5	122.7	225		Cored at 3.5' height.
Fundy Cove Bgum	10/30/1997	Nottingham	ROCK	*Nyssa sylvatica*	12.5	122.7		224	Same tree as 02A, cored at 6" height.
Fundy Cove Bgum	10/30/1997	Nottingham	ROCK	*Nyssa sylvatica*	19.0	283.5	328		cc
Hop-Ev Lake Project	6/12/1998	Warner	MERR	*Nyssa sylvatica*		0.0		160	Missing outer quarter; perhaps ca. 175 years?
Hop-Ev Lake Project	6/18/1998	Warner	MERR	*Nyssa sylvatica*		0.0	385		
Horatio Preserve	10/30/1998	Swanzey	CHES	*Nyssa sylvatica*	9.5	70.9	180		
Horatio Preserve	10/30/1998	Swanzey	CHES	*Nyssa sylvatica*	19.0	283.5	333		
Horatio Preserve	10/30/1998	Swanzey	CHES	*Picea rubens*	22.5		170		
Lake Massabesic	8/26/1997	Manchester	HILL	*Nyssa sylvatica*	27.2	581.1	234		Readable throughout; cored to center; very wide early rings.
Langdon Swamp	11/24/1998	Epping	ROCK	*Nyssa sylvatica*	20.5	330.1	285		cc; very difficult to count.
Langdon Swamp	11/24/1998	Epping	ROCK	*Nyssa sylvatica*	17.4	237.8	223		cc; very difficult to count.
Langdon Swamp	11/24/1998	Epping	ROCK	*Nyssa sylvatica*	16.8	221.7	250		cc; very difficult to count.
Langdon Swamp	11/24/1998	Epping	ROCK	*Nyssa sylvatica*	11.3	100.3	160		cc
Langdon Swamp	11/24/1998	Epping	ROCK	*Nyssa sylvatica*	15.1	179.1	202		cc; Langdon Brook.
Langdon Swamp	11/24/1998	Epping	ROCK	*Tsuga canadensis*			121		Field notes rubbed off collection straw; missing data.
Lyndeboro Bgum	10/2/1997	Lyndeboro	HILL	*Nyssa sylvatica*	19.3	292.5	156		Readable throughout.
Lyndeboro Bgum	10/2/1997	Lyndeboro	HILL	*Nyssa sylvatica*	22.5	397.6	260		254 +6 from missing center.
New Boston	1/14/1997	New Boston	HILL	*Nyssa sylvatica*	38.0				#1; very difficult to read.
New Boston	1/14/1997	New Boston	HILL	*Nyssa sylvatica*	31.3			200	#2; difficult to read
Northwood Meadows SP	11/30/1996	Northwood	ROCK	*Nyssa sylvatica*	28.3	629.0	498		492 +ca. 6 rings to center.
Rte. 28 Bgum	9/25/1997	Alton	BELK	*Nyssa sylvatica*	11.0	95.0	147		Readable throughout; from plot 1.
Rte. 28 Bgum	9/25/1997	Alton	BELK	*Nyssa sylvatica*	11.0				
Rte. 43 Swamp	6/26/1997	Deerfield	ROCK	*Nyssa sylvatica*	20.0	314.2	388		cc

Site	Date	Town	County	Species	DBH	BA	Ring Cnt.	Part. Cnt.	Notes (cc = likely a conservative count)
Rte. 43 Swamp	6/26/1997	Deerfield	ROCK	*Nyssa sylvatica*	16.0	201.1	310		cc; from plot 1, second core.
S Deerfield Bgum Swamp	11/9/1998	Deerfield	ROCK	*Quercus bicolor*	19.0		145		Grainy ring texture near outer rings.
S Deerfield Bgum Swamp	11/9/1998	Deerfield	ROCK	*Nyssa sylvatica*	18.3	263.0	315		Easily readable, uniform ring width throughout.
S Deerfield Bgum Swamp	11/9/1998	Deerfield	ROCK	*Nyssa sylvatica*	26.0	530.9	464		Very fast growing early rings.
S Deerfield Bgum Swamp	11/9/1998	Deerfield	ROCK	*Nyssa sylvatica*	29.5			138	Rotten center (partial core).
S Deerfield Bgum Swamp	11/9/1998	Deerfield	ROCK	*Nyssa sylvatica*	36.0				Rotten center, many rings too faint to count w / confidence.
S Deerfield Bgum Swamp	11/9/1998	Deerfield	ROCK	*Nyssa sylvatica*	35.0			292	At least 100 more in doubt; core is punky + broken up.
S Deerfield Bgum Swamp	11/9/1998	Deerfield	ROCK	*Nyssa sylvatica*	14.0	153.9	105		Nothing unusual ringwise.
S of Mt. Pond/Pawtuckaway SP	11/9/1998	Nottingham	ROCK	*Nyssa sylvatica*	7.7	46.6		97	Cored at 6" height (7.7" diameter).
S of Mt. Pond/Pawtuckaway SP	11/9/1998	Nottingham	ROCK	*Nyssa sylvatica*	6.9	37.4		93	Cored at 2.5' height (6.9" diameter).
S of Mt. Pond/Pawtuckaway SP	11/9/1998	Nottingham	ROCK	*Nyssa sylvatica*	6.4	32.2	100		Cored at 4.5' height (6.4" diameter); core direct to center.
S of Mt. Pond/Pawtuckaway SP	11/9/1998	Nottingham	ROCK	*Nyssa sylvatica*	14.0	153.9	105		
S of Mt. Pond/Pawtuckaway SP	11/9/1998	Nottingham	ROCK	*Nyssa sylvatica*	13.8	149.6	184		Cored directly to center of tree.
S of Mt. Pond/Pawtuckaway SP	11/9/1998	Nottingham	ROCK	*Pinus rigida*			110		
Squam Neck	8/8/1997	Center Harbor	BELK	*Betula alleghenіensis*					Rotten center.
Squam Neck	7/18/1997	Center Harbor	BELK	*Nyssa sylvatica*	27.2			182	Not fully countable; missing big section of center.
Tuttle Swamp Headwaters	11/24/1998	Epping	ROCK	*Nyssa sylvatica*	27.5	593.9	505		cc
Warner Bgum swamp	10/28/1998	Warner	MERR	*Acer rubrum*	7.5		81		
Warner Bgum swamp	10/28/1998	Warner	MERR	*Nyssa sylvatica*	28.0	615.7	540		Upper 1/3 of trunk gone, much decay above, sm. lateral branches.
Warner Bgum swamp	10/28/1998	Warner	MERR	*Nyssa sylvatica*	?				Young site; rotten core.
Warner Bgum swamp	10/28/1998	Warner	MERR	*Nyssa sylvatica*	11.0	95.0	95		
Warner Bgum swamp	10/28/1998	Warner	MERR	*Nyssa sylvatica*	7.0				Many probable false rings; too unclear to count.
Warner Bgum swamp	10/28/1998	Warner	MERR	*Nyssa sylvatica*	24.5	471.4	407		Young site.
Warner Bgum swamp	10/28/1998	Warner	MERR	*Picea rubens*	7		126		Very thin first and last 20 years of growth.
Warner Bgum swamp	10/28/1998	Warner	MERR	*Tsuga canadensis*	7.0		68		Tree just outside plot 2; easily countable rings.
Warner Bgum swamp	10/28/1998	Warner	MERR	*Tsuga canadensis*	11.0		171		Very distinct rings, some extremely thin; easily countable.

Appendix 5. List of 180 vascular and non-vascular taxa recorded in 46 black gum–red maple basin swamp plots.

Taxa are grouped by life form and sorted alphabetically by genera. The Species Code column shows codes that were used for ordination.

HERBS (FORBS, GRAMINOIDS, AND FERNS)	**SPECIES CODE**
Actaea sp.	ACTAEA$
Aralia nudicaulis (wild sarsaparilla)	ARANUDI
Arisaema triphyllum	ARITRI_
Aster acuminatus (whorled aster)	ASTACUM
Aster novi-belgii (New York aster)	ASTNOVI
Athyrium filix-femina var. angustum (northern lady fern)	ATH_ANG
Bidens connata (swamp beggar-ticks)	BIDCONN
Bidens discoidea (small bidens)	BIDDISC
Bidens frondosa (common beggar-ticks)	BIDFRON
Bidens sp.	BIDENS$
Calamagrostis canadensis	CALCAN_
Calla palustris (wild calla)	CALLPAL
Carex arctata (contracted drooping wood sedge)	CARARCT
Carex atlantica	CARATL_
Carex brunnescens	CARBRU_
Carex canescens (silvery sedge)	CARCANE
Carex comosa (bristly sedge)	CARCOMO
Carex crinita (drooping sedge)	CARCRIN
Carex debilis	CARDEB_
Carex folliculata (follicled sedge)	CARFOLL
Carex gynandra (perfect-awned sedge)	CARGYNA
Carex intumescens (inflated sedge)	CARINTU
Carex lacustris (lake sedge)	CARLACU
Carex laxiculmis (loose-stemmed sedge)	CARELAX
Carex lupulina (hop sedge)	CARLUPU
Carex lurida (sallow sedge)	CARLURI
Carex pensylvanica (Pennsylvanian sedge)	CARPENS
Carex radiata (stellate sedge)	CARRADI
Carex scoparia (broom sedge)	CARSCOP
Carex sp.	CAREX$
Carex stricta (tussock sedge)	CARSTR_
Carex trisperma var. trisperma (three-seeded sedge)	CAR_TRI
Chelone glabra (white turtlehead)	CHEGLAB
Clintonia borealis (blue-bead lily)	CLIBORE
Coptis trifolia var. groenlandica (goldthread)	COP_GRO
Cornus canadensis (bunchberry)	CORCANA
Dalibarda repens (false violet)	DALREPE
Dalibarda sp.	DALIBA$
Dennstaedtia punctilobula (hay-scented fern)	DENPUNC
Drosera rotundifolia (round-leaved sundew)	DROROTU
Dryopteris carthusiana (spinulose wood fern)	DRYCART
Dryopteris intermedia (intermediate wood fern)	DRYINTE
Dryopteris sp.	DRYOPT$
Dulichium arundinaceum (three-way sedge)	DULARUN
Equisetum arvense (field horsetail)	EQUARVE
Eriophorum virginicum (tawny cotton-grass)	ERIVIRG
Galium tinctorium (Clayton's bedstraw)	GALTINC
Galium trifidum (northern three-lobed bedstraw)	GALTRIF

HERBS (FORBS, GRAMINOIDS, AND FERNS), continued	SPECIES CODE
Gaultheria hispidula (creeping snowberry)	GAUHISP
Gaultheria procumbens (wintergreen)	GAUPROC
Glyceria acutiflora (sharp-flowered manna-grass)	GLYACUT
Glyceria canadensis (rattlesnake manna-grass)	GLYCANA
Glyceria striata (manna-grass)	GLYSTR_
Huperzia lucidula (shining clubmoss)	HUPLUCI
Iris versicolor (northern blue flag)	IRIVERS
Juncus canadensis (Canada rush)	JUNCANA
Juncus effusus var. solutus (soft rush)	JUN_SOL
Juncus sp.	JUNCUS$
Leersia oryzoides (rice cut-grass)	LEEORYZ
Leersia virginica (Virginia cut-grass)	LEEVIRG
Ludwigia palustris (water purslane)	LUDPALU
Lycopodium dendroideum (round-branch ground-pine)	LYCDEND
Lycopodium obscurum (princess pine)	LYCOBSC
Lycopodium sp.	LYCOPM$
Lycopus uniflorus (common water horehound)	LYCUNIF
Lysimachia ciliata (fringed loosestrife)	LYSCILI
Lysimachia terrestris (swamp candles)	LYSTERR
Maianthemum canadense (Canada mayflower)	MAICANA
Medeola virginiana (Indian cucumber-root)	MEDVIRG
Mitchella repens (partridge-berry)	MITREPE
Onoclea sensibilis (sensitive fern)	ONOSENS
Osmunda cinnamomea (cinnamon fern)	OSMCINN
Osmunda regalis (royal fern)	OSMREG_
Pteridium aquilinum (bracken)	PTEAQU_
Puccinellia fernaldii (fernald's manna-grass)	PUCFERN
Puccinellia pallida (pale manna-grass)	PUCPALL
Sarracenia purpurea (pitcher-plant)	SARPURP
Scirpus cyperinus (woolly bulrush)	SCICYPE
Sium suave (water parsnip)	SIUSUAV
Smilacina trifolia (three-leaved false Solomon's seal)	SMITRIF
Smilax rotundifolia (bullbrier)	SMIROTU
Solanum dulcamara (nightshade)	SOLDULC
Solidago canadensis var. scabra (tall goldenrod)	SOL_SCA
Solidago gigantea (smooth goldenrod)	SOLGIGA
Solidago rugosa (rough goldenrod)	SOLRUG_
Sparganium americanum (lesser bur-reed)	SPAAMER
Symplocarpus foetidus (skunk cabbage)	SYMFOET
Thelypteris noveboracensis (New York fern)	THENOVE
Thelypteris palustris (marsh fern)	THEPAL_
Thelypteris simulata (Massachusetts fern)	THESIMU
Triadenum virginicum (marsh St. John's-wort)	TRIVIRG
Trientalis borealis (starflower)	TRIBORE
Trillium cernuum (nodding trillium)	TRICERN
Trillium undulatum (painted trillium)	TRIUNDU
Typha latifolia (common cat-tail)	TYPLATI
Viola cucullata (blue marsh violet)	VIOCUCU
Woodwardia virginica (Virginia chain-fern)	WOOVIRG
TREES	
Acer rubrum (red maple)	ACERUBR
Amelanchier laevis (smooth shadbush)	AMELAEV
Betula alleghaniensis (yellow birch)	BETALLE
Betula lenta (black birch)	BETLENT
Betula papyrifera (paper birch)	BETPAP_
Betula populifolia (gray birch)	BETPOPU
Fagus grandifolia (American beech)	FAGGRAN
Fraxinus nigra (black ash)	FRANIGR

TREES, continued	SPECIES CODE
Fraxinus pennsylvanica (green ash)	FRAPEN_
Hamamelis virginiana (witch hazel)	HAMVIRG
Nyssa sylvatica (black gum)	NYSSYLV
Picea mariana (black spruce)	PICMARI
Picea rubens (red spruce)	PICRUBE
Pinus rigida (pitch pine)	PINRIGI
Pinus strobus (white pine)	PINSTRO
Prunus serotina (black cherry)	PRUSERO
Quercus rubra (red oak)	QUERUBR
Tsuga canadensis (hemlock)	TSUCANA
SHRUBS	
Alnus incana (speckled alder)	ALNINC_
Amelanchier canadensis (eastern shadbush)	AMECANA
Amelanchier sp.	AMELAN$
Aronia arbutifolia (red chokeberry)	AROARBU
Aronia melanocarpa (black chokeberry)	AROMELA
Berberis thunbergii (Japanese barberry)	BERTHUN
Cephalanthus occidentalis (buttonbush)	CEPOCCI
Chamaedaphne calyculata (leatherleaf)	CHACAL_
Clethra alnifolia (sweet pepperbush)	CLEALNI
Decodon verticillatus (water willow)	DECVER_
Gaultheria hispidula (creeping snowberry)	GAUHISP
Gaultheria procumbens (wintergreen)	GAUPROC
Gaylussacia baccata (black huckleberry)	GAYBACC
Gaylussacia frondosa (dangleberry)	GAYFRON
Hamamelis virginiana (witch hazel)	HAMVIRG
Ilex laevigata (smooth winterberry)	ILELAEV
Ilex verticillata (winterberry)	ILEVER_
Kalmia angustifolia (sheep laurel)	KALANGU
Kalmia latifolia (mountain laurel)	KALLATI
Lonicera canadensis (Canadian honeysuckle)	LONCANA
Lyonia ligustrina (male-berry)	LYOLIGU
Myrica gale (sweet gale)	MYRGALE
Nemopanthus mucronatus (mountain holly)	NEMMUCR
Rhamnus cathartica (common buckthorn)	RHACATH
Rubus allegheniensis (common blackberry)	RUBALLE
Rubus hispidus (bristly dewberry)	RUBHISP
Rubus occidentalis (western black raspberry)	RUBOCCI
Spiraea alba (meadow-sweet)	SPIALB_
Spiraea tomentosa (steeple-bush)	SPITOME
Toxicodendron vernix (poison sumac)	TOXVERN
Vaccinium angustifolium (early low blueberry)	VACANGU
Vaccinium corymbosum (highbush blueberry)	VACCORY
Vaccinium macrocarpon (large cranberry)	VACMACR
Viburnum alnifolium (hobblebush)	VIBALNI
Viburnum dentatum var. lucidum (northern arrow-wood)	VIB_LUC
Viburnum lentago (nannyberry)	VIBLENT
Viburnum nudum var. cassinoides (witherod)	VIB_CAS
Viburnum sp.	VIBURN$
VINES	
Parthenocissus quinquefolia (Virginia creeper)	PARQUIN
Toxicodendron radicans (climbing poison ivy)	TOXRADI

BRYOPHYTES	SPECIES CODE
Bazzania trilobata	BAZTRIL
Bryophyte sp.	BRYOPH$
Hypnum fertile	HYPFERT
Leucobryum glaucum	LEUGLAU
Mnium sp.	MNIUM$
Pallavicinia lyellii	PALLYEL
Pseudobryum cinclidioides	PSECINC
Sphagnum affine	SPHAFFI
Sphagnum angustifolium	SPHANGU
Sphagnum centrale	SPHCENT
Sphagnum cuspidatum	SPHCUSP
Sphagnum fallax	SPHFALL
Sphagnum fimbriatum	SPHFIMB
Sphagnum flexuosum	SPHFLEX
Sphagnum girgensohnii	SPHGIRG
Sphagnum henryense	SPHHENR
Sphagnum lescurii	SPHLESC
Sphagnum magellanicum	SPHMAGE
Sphagnum palustre	SPHPALU
Sphagnum pulchrum	SPHPULC
Sphagnum recurvum	SPHRECU
Sphagnum russowii	SPHRUSS
Sphagnum sp.	SPHAGN$
Sphagnum torreyanum	SPHTORR
Thuidium delicatulum	THUDELI

Appendix 7. Average stem density and basal area by and across black gum–red maple basin swamps.

This appendix contains four tables. The first shows the average stem density (stems/acre) by DBH class and species for the three black gum–red maple basin swamp variants. The second illustrates average stem density by DBH class and species for all black gum–red maple basin swamps. The third shows the average basal area/acre (square feet/acre) by species and variant type. The fourth shows the average basal area/acre by species averaged across all plots and variants.

Species Codes are defined in Appendix 5.

TWINSPAN Groups are:

3 = boggy woodland/tall shrub thicket variant
4 = boggy forest/woodland variant
5 = hemlock forest/woodland variant

Average Stem Density (Stems/Ac) by DBH Class and Species for Black Gum – Red Maple Basin Swamp Variants (TWINSPAN Group 3 = Boggy Woodland/Tall Shrub Thicket Variant, Group 4 = Boggy Forest/Woodland Variant, Group 5 = Hemlock Forest/Woodland Variant)

			DBH Class (in.)																	
			2-4		4-8		8-12		12-16		16-20		20-24		24-28		>28		Snags	
Group	Species Code	No. Plots	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
3	ACERUBR	10	10	9	26	17	16	19	11	7	4	5	0	0	0	0	0	0	19	26
3	BETALLE	10	6	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	BETLENT	10	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	BETPOPU	10	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	NYSSYLV	10	39	55	33	21	25	12	32	31	16	15	9	10	0	0	0	0	7	13
3	PICRUBE	10	3	7	5	10	0	0	1	3	0	0	0	0	0	0	0	0	2	6
3	PINSTRO	10	0	0	1	3	1	3	0	0	0	0	0	0	0	0	0	0	1	3
3	TSUCANA	10	17	32	7	16	0	0	0	0	1	3	0	0	0	0	0	0	3	5
4	ACERUBR	7	42	58	61	73	24	14	7	19	4	5	4	10	0	0	0	0	6	5
4	BETALLE	7	22	22	11	13	1	4	0	0	0	0	0	0	0	0	0	0	11	22
4	BETLENT	7	0	0	3	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	NYSSYLV	7	13	20	27	28	27	27	14	19	11	9	7	5	3	5	3	5	3	5
4	PICRUBE	7	17	19	25	29	7	13	0	0	0	0	0	0	0	0	0	0	7	13
4	PINSTRO	7	1	4	3	5	12	14	6	8	0	0	0	0	0	0	0	0	1	4
4	TSUCANA	7	32	32	32	38	20	26	4	8	0	0	0	0	0	0	0	0	14	21
5	ACERUBR	13	32	38	51	35	29	34	17	14	2	6	2	8	0	0	0	0	11	13
5	AMELAEV	13	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	BETALLE	13	27	30	14	17	4	9	1	3	0	0	0	0	0	0	0	0	22	39
5	BETLENT	13	2	4	1	2	1	3	0	0	0	0	0	0	0	0	0	0	0	0
5	BETPOPU	13	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	FAGGRAN	13	0	0	3	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	FRANIGR	13	1	3	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	NYSSYLV	13	33	43	47	62	28	31	29	41	13	17	8	13	5	9	2	4	4	6
5	PICRUBE	13	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	PINSTRO	13	1	2	6	10	4	10	2	6	2	6	0	0	0	0	0	0	4	10
5	QUERUBR	13	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	TSUCANA	13	62	51	39	40	16	15	12	15	2	6	0	0	0	0	0	0	13	15

Average Stem Density (Stems/Ac) by DBH Class and Species for All Black Gum – Red Maple Basin Swamp Plots

		DBH Class (in.)																	
		2-4		4-8		8-12		12-16		16-20		20-24		24-28		>28		Snags	
Species Code	No. Plots	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
ACERUBR	30	27	38	45	44	24	26	13	14	3	5	2	7	0	0	0	0	12	18
AMELAEV	30	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BETALLE	30	19	24	9	14	2	6	0	2	0	0	0	0	0	0	0	0	12	29
BETLENT	30	1	3	1	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0
BETPOPU	30	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAGGRAN	30	0	0	1	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FRANIGR	30	0	2	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NYSSYLV	30	30	43	38	45	27	25	27	34	14	14	8	10	3	6	2	4	5	9
PICRUBE	30	5	12	8	18	2	7	0	2	0	0	0	0	0	0	0	0	2	8
PINSTRO	30	1	2	4	7	5	10	2	6	1	4	0	0	0	0	0	0	2	7
QUERUBR	30	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TSUCANA	30	40	45	27	35	12	17	6	12	1	4	0	0	0	0	0	0	10	14

Average basal area/acre (sq ft/ac) by species and Twinspan Group (averaged across all plots in each group)										
		DBH class (inches)								
Twinspan Group	code	2-4	4-8	8-12	12-16	16-20	20-24	24-28	>28	Total Basal Area by Species
3	ACERUBR	0.51	5.14	8.98	11.40	7.15	0.00	0.00	0.00	33.19
3	BETALLE	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28
3	BETLENT	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
3	BETPOPU	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
3	NYSSYLV	1.92	6.56	13.59	34.27	28.07	24.79	0.00	0.00	109.20
3	PICRUBE	0.14	0.99	0.00	1.08	0.00	0.00	0.00	0.00	2.21
3	PINSTRO	0.00	0.20	0.55	0.00	0.00	0.00	0.00	0.00	0.75
3	TSUCANA	0.83	1.39	0.00	0.00	1.79	0.00	0.00	0.00	4.01
4	ACERUBR	2.04	11.98	13.23	7.73	7.38	10.17	0.00	0.00	52.53
4	BETALLE	1.08	2.14	0.79	0.00	0.00	0.00	0.00	0.00	4.01
4	BETLENT	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.50
4	NYSSYLV	0.63	5.30	14.98	15.45	20.15	18.65	10.66	13.40	99.21
4	PICRUBE	0.84	4.95	3.94	0.00	0.00	0.00	0.00	0.00	9.73
4	PINSTRO	0.07	0.57	6.31	6.18	0.00	0.00	0.00	0.00	13.12
4	TSUCANA	1.55	6.37	10.77	4.64	0.00	0.00	0.00	0.00	23.33
5	ACERUBR	1.55	10.05	15.99	18.12	4.13	6.16	0.00	0.00	56.00
5	AMELAEV	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
5	BETALLE	1.31	2.75	1.98	0.83	0.00	0.00	0.00	0.00	6.87
5	BETLENT	0.09	0.10	0.42	0.00	0.00	0.00	0.00	0.00	0.62
5	BETPOPU	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
5	FAGGRAN	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.54
5	FRANIGR	0.04	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.34
5	NYSSYLV	1.60	9.29	15.37	31.43	22.77	21.68	17.22	11.46	130.82
5	PICRUBE	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
5	PINSTRO	0.03	1.15	1.93	2.31	3.82	0.00	0.00	0.00	9.24
5	QUERUBR	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.15
5	TSUCANA	3.06	7.62	8.77	12.48	4.13	0.00	0.00	0.00	36.06

Average basal area/acre (sq ft/ac) by species (averaged across all plots and Twinspan groups)									
	DBH class (inches)								
Species Code	2-4	4-8	8-12	12-16	16-20	20-24	24-28	>28	Total Basal Area by Species
ACERUBR	1.32	8.87	13.01	13.45	5.89	5.04	0.00	0.00	47.58
AMELAEV	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
BETALLE	0.91	1.69	1.04	0.36	0.00	0.00	0.00	0.00	4.01
BETLENT	0.05	0.16	0.18	0.00	0.00	0.00	0.00	0.00	0.40
BETPOPU	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
FAGGRAN	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.24
FRANIGR	0.02	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.15
NYSSYLV	1.48	7.45	14.69	28.65	23.92	22.01	9.95	8.09	116.24
PICRUBE	0.26	1.49	0.92	0.36	0.00	0.00	0.00	0.00	3.02
PINSTRO	0.03	0.70	2.49	2.44	1.66	0.00	0.00	0.00	7.32
QUERUBR	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.07
TSUCANA	1.96	5.25	6.31	6.49	2.38	0.00	0.00	0.00	22.41